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AMERICAN FOREST REGULATION.

WOOLSEY.

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AMERICAN FOREST REGULATION

BY

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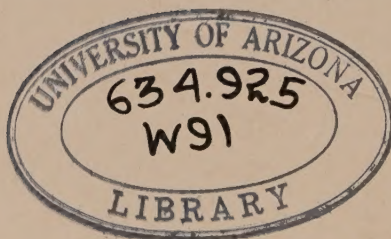
Lecturer Yale School of Forestry, 1912, 1916-1917



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AMERICAN
FOREST REGULATION

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Part I and appendix, Theodore S. Woolsey, Jr.
Part II, Herman H. Chapman



TO
JAMES W. TOUMEY
IN RECOGNITION OF HIS SERVICES
AS A TEACHER OF FORESTRY
IN THE YALE SCHOOL OF FORESTRY

10

JAMES W. JORDAN

IN FOSTON/THOMAS H. JORDAN

AS A MEMBER OF THE

OF THE VALE GROUP OF INDUSTRIES



1917

PREFACE

"American Forest Regulation" is intended primarily as a textbook on the theory and application of regulating the cut. It may also serve as a guide for forest administrators who must solve broad regulation problems at a reasonable cost. Emphasis has been placed on the discrimination and choice of material, rather than the collection and elaboration of a multitude of facts—many totally unsuited to American conditions. Forest management in the United States cannot be successful until it is definitely recognized that the cutting on all forests held for permanent production must be controlled by working plans based on sound silviculture, local economic requirements and rate of yield.

At the least perplexing of the problems encountered has been the question of terminology. The author, a member of the Committee of the Society of American Foresters, which recommended standard terms* and definitions, followed the Committee's report, except where it departs from well established common usage. "Working circle" has accordingly been substituted for "working unit." The student who is assigned additional reading study in the works of other authors, cannot help but be confused by a haphazard use of terms. For example, "working group" may be termed "work-section" by one author, "working figure" by another, and "working circle" by a third. The "working unit" of the S. A. F. again may be described as "working circle" by Sir William Schlich**, thus further perplexing the student. The writer felt that no personal preference for terms should enter into this book on American Forest Regulation but that "working circle," widely used in the United States, was preferable to "working unit." On the other hand, the new term "management plan," largely used by the Forest Service in place of the term "working plan" (adopted for generations by English foresters), has not been adopted.

To simplify study, the regulation of cut methods in Part I have been treated systematically, as follows: (1) Definition, (2) Discussion, (3) Illustration, (4) Class room questions or quiz. This plan has not been rigidly adhered to so far as the subject matter lends itself to this form of treatment, it has varied throughout. Formulae have first been stated in English (instead of "formulae equivalents") because the writer found they were more readily understood by the student. A special feature is quite complete foot-note references to American Literature on each subject.

A rather theoretical discussion of soil-rent (after Endres) has been given, notwithstanding the fact that it is likely that a large proportion of the best American forests will eventually be owned or controlled by the public, and consequently need not necessarily be managed strictly on the basis of the

* Published in 1917 in the *Journal of Forestry*, Vol. XV, No. 1.

** Schlich, Sir William, *Manual of Forestry* (Forest Management, Vol. 3, p. 273).

highest soil-rent. Yet this financial side may eventually be of weight in planning the management of many private American forests, where business reasons may usually be foremost. Because of this considerable space in the appendix has been given to a frankly Germanized explanation of soil-rent and to Endres' discussion and illustration of its application.

The contrast between French and German text-book methods is evident even to the casual reader. The German is apt to treat the subject extensively; he will describe twenty different formulae, each varying from the other ever so little, while the French writer will perhaps narrow the formulae down to three fundamental and radically different methods, and omit the others. This book (with the exception of soil-rent) has been written from the French rather than from the German viewpoint, and, consequently, may be characterized by its simplicity rather than in the complexity of subject matter. Commenting on this very feature of German thoroughness and complexity, Sir William Schlich states:*

"Of the seventeen methods described several have only an academic interest, and much, and all of the others have for their object to secure a sustained yield by grasping such a proportion between the different age classes that each shall, as far as possible, occupy about the same area, whether they are found on different areas scattered over the whole forest . . . there is not nearly so much difference in the several methods as their inventors believe."

This viewpoint explains why the author of this volume has omitted the usual elaboration of textbook methods and formulae which differ from one another in some minor degree.

Rather than include data on American working plans which are usually preliminary in character, the writer has omitted the usual treatment of this phase of organization. In Appendix A—E some "working plan" examples have necessarily been included so as not to mar a complete translation of a portion of Martin's *Forsteinrichtung*.

Acknowledgment has been made in the foot-notes for material borrowed directly from other sources, but necessarily many of the ideas and much of the data included, have been absorbed and adapted from text-books on the same subject, especially from Volume III (Fourth edition) *Manual of Forest Management* by Sir William Schlich; from *Lehrbuch Waldwertrechnung und Forstwirtschaft* by Max Endres; and from Volume III, *Economie Forestière* by G. H. Rieu. The description of regulation in the various German states and in Austria given in the appendix is translated from Martin's *Forsteinrichtung*. Acknowledgment is also due C. E. Carter (of Australia), Yale School of Forestry, 1922, T. S. Hansen, Yale School of Forestry, 1917, T. T. Munger, U. S. Forest Service, E. J. Hanzlik, U. S. F. S., E. Koch, U. S. F. S., and M. H. Wolff, U. S. Forest Service, for a review of and a critical comment on the manuscript of Part I.

When the original plan of February 1, 1917 of publishing under joint authorship with Professor Chapman had to be abandoned, the following acknowledgment was agreed upon:

"This manuscript was (largely) written in 1917, with the consent and coöperation of H. H. Chapman. The technical order and arrangement followed the Yale lecture

* Sir William Schlich (*Quarterly Journal of Forestry*, 1913, p. 201).

Prof. Chapman, but the American and European details and references and scheme of treatment, are original with the writer. The manuscript was revised and completed by the writer in 1920 (1921). While Prof. Chapman assumes no responsibility, whatever, as to technical details, the writer wishes to acknowledge his very great indebtedness to him for the use of his notes as a guide. Those who took his lectures at Yale will recognize just how great this indebtedness is."

In 1920 Prof. Chapman kindly agreed to contribute Part II on "Correlation of Regulation and Growth in Extensive American Forests," with the understanding that the book would be immediately published under my authorship. The slight duplication of Part I in Part II is an advantage rather than a detriment and Chapman's comment on the correlation of growth and regulation is invaluable.

When chief of silviculture in the Forest Service, District No. 3, the need for regulating the cut of timber on National Forests was very apparent. In giving the courses in management at the Yale School of Forestry, 1916-17 (when Professor Chapman took my place in the West) I was convinced that regulation had been misunderstood and neglected in the United States and that, therefore, there was an immediate need of a thoroughly Americanized edition on this essential and important phase of forest management. The opportunity of service with the A. E. F. in France explains the four years delay in publication, but I am certain that the need for such a book to-day is more acute.

THEODORE S. WOOLSEY, JR.

Haven, Conn.
December, 1921.

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SYMBOLS USED

SYMBOL	EQUIVALENT
n	Normal growing stock.
a	Real or actual growing stock.
	Normal.
	Rotation.
	The difference between the age when the tree reaches merchantable size and the rotation age.
	Age when tree reaches merchantable size.
	Increment (c. a. i. and m. a. i. are symbols for current and mean annual increment).
	Number of years.
n	Normal yield.
a	Real or actual yield.
	Number of years within which to distribute the surplus or deficit.
%	Mortality per cent (M is the symbol for German marks in appendix A).
ft.	1,000 feet board measure.
c	Cutting cycle.
res.	Timber reserved after cutting.
\$	Final yield (in dollars).
\$	Intermediate yield (in dollars).
\$	Expenditures (if annual, symbol is AE\$) capitalized.
\$	Costs (initial).
, b, etc.	Yield table figure for yield at 10 years, 20 years, etc.
A	Area.

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	Number of years within which to distribute the surplus or deficit.
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1 ft.	1,000 feet board measure.
c	Cutting cycle.
res.	Timber reserved after cutting.
\$	Final yield (in dollars).
\$	Intermediate yield (in dollars).
\$	Expenditures (if annual, symbol is AE\$) capitalized.
\$	Costs (initial).
, b, etc.	Yield table figure for yield at 10 years, 20 years, etc.
A	Area.

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INTRODUCTORY

By B. E. FERNOW

The question is sometimes raised—even in professional circles—whether silviculture or forest regulation (organization) is the more important subject. To raise this question is like inquiring whether the shelves in the library are more important than the books, the implements used in raising a crop more important than the crop itself. Nevertheless as suggested by Æsop's noted fable on the quarrel of the members, forest regulation (organization) is absolutely essential for a well conducted forestry business, just as the systematic management of a factory is all important to the success of that business.

In applying the various methods of regulation, the needs of silvicultural operations must necessarily produce modifications of the mathematics involved in regulating the felling budget. How far these silvicultural considerations are to influence the economic considerations will depend upon the character and the interests of the owner. For instance for forests under State ownership the interests of the future could and should dominate and more economic or financial sacrifices may be justified in attaining the normal forest than is the case in private ownership. The conditions for an economic sustained yield may be more rapidly attempted by the former, while the latter may be satisfied with a mere *silvicultural* sustained yield, i.e., keeping the land in forest. Conditions vary so greatly that it is impossible to lay down principles. Compromises will be necessary which depend upon the financial ability and other modifying circumstances of the owner.

The forestry business has an advantage over most other businesses in that its ideal formulated, namely in the normal forest (with its normal growth, stock, age class gradation, and distribution, and normal increment), consciously and expressed or unconsciously and unexpressed. As with all ideals, practical considerations and conditions keep us from attaining them fully, and the problem for the forester is always how far he will sacrifice present advances to this ideal of the sustained yield forest.

It should be borne in mind that the European methods of regulation represent a historic evolutionary series, each one having acceptable features which have been borrowed by the next. With modern means of transportation, the need of making any small forest completely normal has become less imperative and has permitted the freedom of handling it à la Judeich. Moreover the extensive application of the division and allotment methods had brought about the existence of suitable age classes when the stand method became practicable. Although only one state (Baden) has adopted the Karl Heyer (see paragraph 85) method of regulating the forest, I am inclined to consider this method the most practical in attaining a normal forest condition without too much sacrifice *if carried out in Heyer's spirit*. It will also be applicable in the United States in many cases.

The effort of investigating the applicability of European methods and of developing American methods, as attempted in this volume, is one which is worthy of all praise.

B. E. FERNOW.

PART I

POLICY AND THEORY OF REGULATION

CHAPTER I

INTRODUCTION TO FOREST REGULATION

Definition and Significance of Forest Regulation. Forest Regulation* (organization) is that branch of forestry which concerns itself with the organization of a forest property for management and maintenance, ordering in and place the most advantageous use of the property, with the aim of securing sustained yield. The broader term forest management includes all subjects dealing with the inventory, condition, and proper and systematic development of forest resources, and the organization and administration which will secure continuous productiveness. Regulation aims chiefly at continuity of productiveness but also at utilizing to the fullest extent the resources under forest management; the normal timber capital is property held in trust, while the cut substitutes the owner's returns. It is the most important ultimate goal of the forester to bring his forest property to a sustained yield so as to produce a nearly equal annual or periodic return. It is only by systematic regulation that permanent economic production can be secured. This principle of sustained yield is of importance to the individual and to the nation. It is primary for the private owner to require equalized returns on his investments and the wood industry of the nation also requires fairly sustained annual production in order to keep wood-using industries in full operation. Serious depression, when industrial production is curtailed, may warrant a corresponding diminution of output from public and private forests. On the

It is important to differentiate clearly between forest economics, forest economy, forest finance, forest management, forest mensuration and forest regulation.

Forest Economics (*syn. Forest Policy*). A comprehensive term including all matter relating to the position of forests in public affairs.

Forest Economy. A comprehensive term including all matter dealing with the business aspects of forest management. (See also Fernow, B. F., *Economics of Forestry*, 1933, 5th edition, New York.)

Forest Finance. That branch of the science of forestry which relates to the forest as an investment. It includes two distinct subjects, Forest Valuation and Forest Statics; the first concerning valuations of soil and growing stock, increment, and damage; the second with a comparison of the financial results of different methods of treatment and questions of profitableness and financial effects.

Forest Management. The practice of the application of forestry in the conduct of the forest business.

Forest Mensuration. That branch of forestry which deals with the determination of volume of stands, trees, logs and other timber products, and with the study of growth and yield of trees and stands.

other hand, in times of stress, as was evidenced in France during the a nation is fully justified in over-cutting its public and private forest the good of the state.

Of the technical factors which lead to an assured annual yield, the important is the age of the different stands. For it is evident that if a timber in a forest is immature, there can be no production of sawtimber until these individual stands ripen. If, however, all the timber is mature, the problem of securing a continuous yield of sawtimber may be assured, provided the owner is willing to make certain sacrifices, often obligatory. A part of the decadent and overmature timber is held without cutting for long periods.

Russell and Roth (see § 12) have pointed out the hiatus in national timber production which is sure to follow our present era of destructive lumbering. Our national timber resources are largely composed of virgin stands of mature and decadent timber and of idle cut-over land, much of it barren or partially stocked with valuable species; aside from woodlots there is little forest land today in the United States stocked with middle-aged timber, therefore it is easy to visualize what will happen when our virgin stands are destroyed; the nation surely will be confronted with a shortage of timber land stocked with merchantable timber. Our publicly owned forests will be insufficient in area to supply national demands. Even if we wake up to the need for permanent forest production before all our virgin timber is gone, we cannot now repair the damage in time to avert a serious shortage, because it takes from 60 to 120 years or more (see chapter IV-V) to produce *sawtimber* as contrasted with *cordwood*. Even if every acre of potential forest land were fully stocked with valuable immature timber, when the last of our virgin stands disappears, many sawmills must shut down until these immature trees ripen. We would be in much the same situation as England was when the demand for ammunition overran the supply. Factories capable of enormous production were being built but had not yet reached the production stage. Fortunately, in the industrial world such a shortage can soon be relieved, but in forest management we must face squarely the hiatus in production sure to occur if there are no middle-aged stands ready to grow into merchantable timber that is certain to be required by our rapidly increasing population.

The owner of merchantable timber when deciding upon the proper cutting policy to adopt has three alternatives:

(1) In anticipation of higher prices due to the predicted timber shortage, he may carry his timber as a speculation;

(2) He may rapidly convert his stumpage into money and realize on his forest investment. High taxes and heavy carrying costs on forest and land investments have induced practically all American lumbermen to follow this course; or,

(3) He can make a compromise between (1) or (2); but after the c

* Of course virgin stands contain young and middle aged timber but this is usually all destroyed by "destructive lumbering."

Decided not to hold his timber as an investment against higher prices to realize on his forest, there is still the important decision, *how much to and when*. This question must be answered by applied regulation, which should always aim at a sustained yield of timber and permanent production. Does without saying, as Dr. Fernow has emphasized in his Introductory, that regulation cannot be successful without sound silviculture, nor are the two incompatible. *Re-growth*, ordinarily by natural regeneration, will always remain the *sine qua non* of successful forest management in the United States.

Conception of Regulation in Europe. It is instructive to see what the European idea of regulation is in the exact words of great foresters. Huffel,* foremost French authority says: "The management (or regulation) of forest includes all operations which aim at systematizing the cut." He says that public forest owners have only the right to *income* from properties and must pass the *principal* on to the future generations unimpaired; that this is the fundamental idea of forest regulation. He admits, however, that private owner should be given more freedom in the use of his property according to his individual needs. All owners are, however, benefited by systematic forest working plans, "which indicate for a definite period, (1) the date, (2) the method, (3) the location, (4) the extent (degree) of all changes which will be made in the forest." The German and Austrian definitions** emphasize profit, orderliness and sustained yield: Judeich (Saxony) says:

"The object of forest management is the most profitable use of soil or land for raising timber..... The task of regulation is to order in time and place the entire management or business of the forest, in such a manner that the object of the management is accomplished as fully as possible."

According to Martin (Prussia and Saxony) forest regulation,

"comprises the measures necessary to conduct an orderly forest management..... Regulation forms the most important subject of instruction in the business of management of the forest..... The most important object of regulation is to direct the order or progress of the harvest or cut and the removal of the several stands of timber..... The most difficult and yet the most important task in the preliminary work is a suitable division of the forest into permanent sub-divisions."

von Guttenberg (Austria) defines regulation as,

"that part of the science of forestry (and particularly of forest management) which attempts a well planned order and arrangement of the entire management of a forest, and especially the regulation of the cut in order to assure the most profitable and sustained yield or income from the property."

Goetzer (Saxony) also bears on the sustained yield idea and adds other details to his definition of what regulation is:

*Huffel, G., *Économie Forestière*, Tome Troisième, 1907, pp. 4, 7, 8, 12.
Adapted from the appendix of F. Roth's *Forest Regulation*, pp. 203-218.

".....It maintains order in the management of a forest; it regulates particularly the manner and time of cutting.....; it plans to restock land with new stands of trees, and it determines the amount of timber which may be cut each year without diminishing the wood capital or endangering the continuance of such a cut for the future..... The provisions of forest regulation are not employed for individual stands of timber, cut at intervals of many years, but apply to forests where a yearly cut of timber is produced and is demanded."

3. Scope of Regulation. As a matter of fact, the correct regulation of a cut on a forest requires a complete and detailed study of all local and general conditions. Regulation depends on correct answers to the economic, business and technical problems presented. It is most intimately linked with Stock taking and growth, included in mensuration (Business group), Policy and history (Economics), (c) Forest finance (Business), and (d) Silviculture, protection and lumbering (Technical). But the more the following diagram (after Chapman, page 4, *Forest Mensuration*, John Wiley & Sons) is studied, the clearer becomes the interrelation between forest regulation and the parts of the physical, mathematical and human groups:

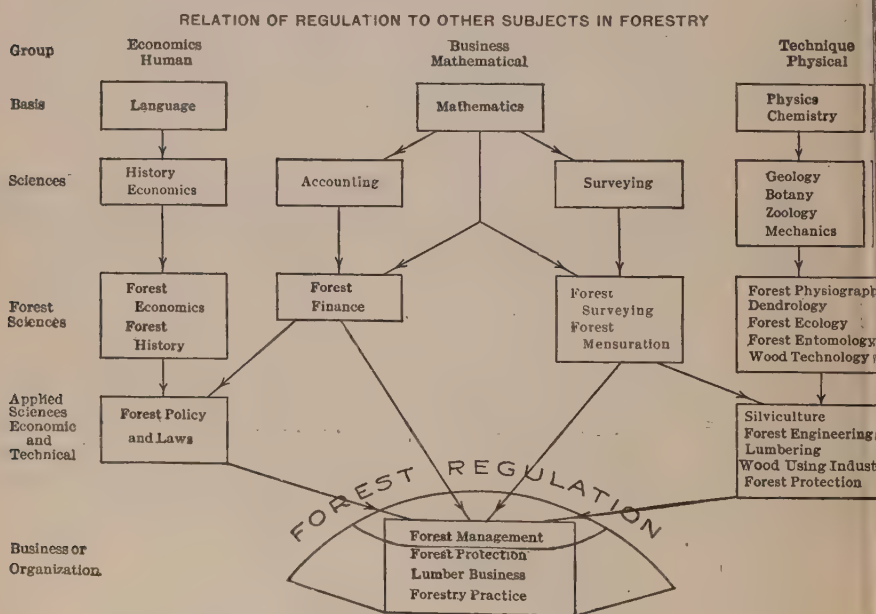


FIG. 1.

4. Land Classification, an Initial Step. As our industrial development continues, land originally classified as chiefly valuable for forest production may eventually be devoted to other uses. But before regulation can be intelligently planned, it is obviously necessary that the land classification must clearly differentiate for the time being between agricultural and forest soils. If the estimate of permanent production is based partly on stands growing on agricultural land soon to be cleared, the whole arrangement

interrupted if this land must be withdrawn from the forest for purely cultural uses.

Details Must be Systematized in Working Plans. Forest Regulation or Forest Organization is therefore the systematic and orderly presentation of business* of Forest Management usually embodied in a formal *working plan* which is:

the plan or plans under which a given forest property is to be continuously managed. Annual or periodic plans may be based on the general working plan and may refer to any specified class of work, as the annual cutting, planting, thinning, grazing, or administration and improvement plan.

Each annual plan may be either mere schedules or may contain more or less details, explanations, estimates of cost and results, as seems desirable.

Details of forest management must be systematized to avoid waste. The present and the future policy upon which forest management is based must be clearly presented to the manager and the basic local economic data** concerning the area must be collected so the forest can be divided to suit the demands of silviculture and intensiveness of treatment. Then the essential regulation of cut—the soul of forest regulation—can be determined and the amount to cut each compartment decided upon. In American forest regulation silviculture will usually take precedence over the mere dictates of forest mathematics, but the two of course should be correlated.

Without system, the work of one manager is lost to his successor. The manager who “carries the data in his head” is the forester of the past generation; he is the sort of man who is eliminated by the modern board of directors who insist on constructive business efficiency.

Progress of American Regulation in Early Working Plans. The progress of Forest Regulation in a country is a sure indication of the intensiveness of forest administration. Every annual report in British India catalogues the *area under working plans*, because this is considered a criterion of advancement. But in the United States, curiously enough, while the initial work of forested foresters was early centered in the preparation and publication of working plans for private timber lands, yet today there are few plans for public forests, although the regulation ideal has never been lost sight of. Judging from the interest in management that has arisen during the past century (see appendix E), the present lack of really effective National Forest administration will soon be remedied.

The earliest published plan*** set the standard for private working plans and original diameter limit methods* of regulating the cut which were blindly followed in other countries without regard to type, or character of cutting and silviculture. A method which might give passable temporary results in the tolerant spruce forests of the Adirondacks

Chapman, H. H., *Working Plans* (P. S. A. F., Vol. X, pp. 376-383, 1915).

Chapman, H. H., *Forest Mensuration*, John Wiley & Sons, New York, 1921.

Graves, H. S., *Practical Forestry in the Adirondacks* (Bureau of Forestry Bulletin,

Moore, Barrington, *Working Plans: Past History, Present Situation, and Future Development*. (P. S. A. F., Vol. X, pp. 217-259.)

naturally failed when applied without modification to almost clear cutting intolerant pineries of the South.

According to Olmstead,*

"The yield to be expected from cutover lands shows a high return from the invested in them cutting to twelve inches breast high (fourteen stump) with stumpage at two dollars (now one fifty), land at one dollar an acre the annual interest represented by the future crop on cutover lands for a period of forty years, is nearly nine per cent The lands which have been cutover will be producing timber, which at a conservative estimate represents an interest of 8.8% on the capital invested in them."

This calculation applies to short-leaf and loblolly pines in the South, but Fernow says, "The real interest which the above quoted example will give is about 7%. This is considerably different from 9%."

The reason why working plans for private lands were so important a part of the work of the Bureau of Forestry (prior to the establishment of the Forest Service on February 1, 1905) was that these were but a means to an end—a useful method of advertising forestry, a propaganda which proved entirely successful in enabling the technical bureau to assume charge of the National Forests (then termed Forest Reserves). The technical failures of these early plans according to one writer,** due to putting future interests ahead of the present, a failure to understand the lumberman's wanton destruction of forests was dictated by economic factors. The latter shortcoming was because they had not received a proper business training. These plans attempted the impossible and copied too closely the European counterparts. Where less was attempted, a greater measure of success was secured.* This activity in working plans was under the artificial stimulus of a propaganda campaign. A measure of technical success it is true was attained in the woodlot plans because the main emphasis was placed on silviculture (and especially on the immediate production of sample thinnings) rather than on regulation.

7. Stock Taking by the Forest Service Preliminary to Regulation. When on February 1, 1905 the Bureau of Forestry was given the National Forests to administer, the problems of organization, fire protection, grazing, improvement and the sale of timber occupied the attention of those in charge. Sporadic attempts were made to draw up *preliminary* working plans but the main expenditures during the next decade were on mapping and estimating. These data were for timber sales and for rough purposes of regulation to prevent overcutting. Generally speaking these early estimates have proved too inaccurate for the modern timber sale appraisal unless corrected by comparing them with the results of cutting in timber sales—and even then the results are not wholly satisfactory. All of the rough estimating eventually will have to be done over again. This was to be expected and it can safely be said that as a policy a rough estimate for every forest was entirely proper because it cost perhaps but a cent or two an acre. As a result of no economic development more accurate estimates will be justified later. Forest history certainly justifies the rough timber survey of a forest area.

* Olmstead, F. E., "Working Plan for Forest Land Near Pine Bluff, Ark." (Bureau of Forestry, Bulletin 32, 1902, page 44.)

** Fernow, B. E. (Forestry Quarterly, Vol. 1, page 32, note).

*** Ibid., pp. 221-222.

* Foley, John. Conservative Lumbering at Sewanee, Tennessee. (Bureau of Forestry, Bulletin 39, 1903.)

initial step in regulation. Only high stumpage prices and intensive estimates justify costly and intensive estimates. Preliminary regulation requires not only a knowledge of the resources but equally important, systematic data on the marketing, manufacture, and utilization of the product and basic information on silvicultural practice. During this initial period of development no satisfactory or practical regulation scheme was developed, notwithstanding a number of attempts. According to the 1919 Forest Service Manual (Reg. S-2), the limitation of cut is now as follows:

The Secretary of Agriculture will prescribe from time to time, upon data furnished by the Forester, the maximum amount of matured and large-growth timber which may be cut by years or other periods, on each National Forest or other unit." In many countries the annual cut is fixed by the Secretary (the ranking official) since technical services in principle should not establish the allowed cut for the forests to supervise. Probably more effective results would be obtained in the United States if the limitation of cut on National Forests were checked and correlated by an independent forestry advisor *actually serving* in the office of the *Secretary of Agriculture*. At present the limitation of cut figures are prepared by the Forest Service and the Secretary's approval is purely perfunctory. But such a plan of re-organization will probably be adopted because of the additional cost. Many efforts are continued to systematize estimating and mapping, since accurate estimation of cut as a vital problem by itself can only follow reliable estimating which is dependent on appropriations; until very recently estimating on National Forests was frankly based chiefly on timber sales demands but now the policy has been changed so as to give more emphasis to obligatory regulation.

Regulation on Privately Owned Property. Strictly speaking, there has been no regulation on private, state, or institutional lands.

At the Vanderbilt property near Asheville (now Pisgah National Forest and Game Preserve) silviculture dominated the early cutting policy, but today the forest is being heavily culled prior to its being turned over to the United States. On the Whitney and other tracts in the Adirondacks the regulation of cut has been made subservient to a business showing. Yale has managed the forest property of the New Haven Company,* but systematic regulation has not been commenced because good silviculture demanded the removal of diseased chestnuts, and a formal working plan has thus far been deemed unnecessary. Improvement thinnings and planting rather than regulation was what the forest needed. Similar conditions have dictated the policy at Swannee, Tennessee and at Syracuse, N. Y. (State College of Forestry), where the adjacent school forests are being successfully managed. Of college forests the Harvard Forest alone has been really regulated during the past ten years.

Silviculture must come first, to be sure, but during the initial period, it is often only too easy, even for technical forest schools, to minimize the need for systematic mandatory regulation. It is predicted that regulation will come into increasing prominence during the next decade. For without a systematic attempt to regulate the forest for continuous production in accordance with correct silviculture, forest management cannot be put into effect.

Quiz. What is the distinction between forest regulation and forest finance? mensuration?

What are the essentials of a definition of regulation?

In what particulars do different authors vary in their definitions of regulation?

Why were working plans made for private timber lands prior to 1905?

How was forestry benefited by this?

Why did these plans fail technically?

Why were calculations of profit too high?

Why are working plans now being developed for National Forests?

Why were rough timber surveys justified?

What restrictions as to timber sales are now made by the Forest Service?

Which should come first, silviculture or regulation; should the two be correlated?

What replaces regulation on privately owned forests and why?

CHAPTER II

BACKGROUND OF A REGULATION POLICY AND SUSTAINED YIELD

Basic Conditions. Gifford Pinchot, in an address delivered in 1921, stated that the United States must have a National forest policy for the preservation and regulation of forests. More than half of our original timber has been cut and burned away. We are cutting what remains more than ten times faster than it is being reproduced. Three-fourths of what we now have will be cut within twenty-five years. When our own timber is exhausted, neither in Canada nor in Mexico nor elsewhere in all the world can we get the kinds and quantities of timber that we need. The supply of timber is indispensably necessary to keep our agriculture, mining, manufacture and transportation productive and prosperous is the greatest and the far reaching economic question now before the people of the United States.

One-fifth of the timber of the United States is in State and National Forests (most wholly in the latter). Four-fifths is in private hands, and is being cut as rapidly as ever. If we are to mitigate or escape the timber famine which is now clearly ahead, forest devastation on the privately owned commercial timberland must stop. Already more than eighty million acres of forest lands in America have been so completely devastated that they produce nothing, and the lumbermen are extending this devastation every year over a total of new land as large as the whole State of Connecticut. A National forest policy, to be effective, must put a stop to forest devastation, control or prevent forest fires, and provide for raising at home the timber without which the United States cannot even exist as an organized community, to say nothing of the safety, prosperity and comfort of our people. The forest policy of the United States, Mr. Pinchot points out, must be nationwide for many reasons. Already more than three-fourths of our people live in the states whose forests are unable to supply their own needs in timber. All of our greatest agricultural and industrial communities are in the thirty-three timber-importing states. The timber-importing states are rapidly increasing in number and the timber exporting states rapidly diminishing. The timber-importing states contain four-fifths of our agricultural lands, and nine-tenths of our manufactures are produced in them. Seventy per cent of the lumber used in America is consumed outside the state in which it is cut. Half of the timber left in the United States is in the three states of Washington, Oregon, and California, which contain but five per cent of our population. How to get lumber is a far more pressing problem in the states which do not have it than for the states which do. It takes more wood used in more ways to feed, clothe, and house the city dweller than the farmer or the mountaineer—the people far from the forest than those who live in or near it. The only way to prevent control of lumbering on

privately owned timberlands from imposing unfair and unequal burden to make it National and, therefore, uniform throughout the Nation. The only control that can be impartially enforced is National control. The only control that can be kept free from politics is National control. National control can be adapted to local conditions fully as well as state control. The only organization prepared to enforce control, with full knowledge, experience, and undisputed character and ability, is the United States Forest Service, which has been doing with marked success in the National Forests almost exactly what National control would have it do on commercial timberlands. National control through the power to tax is simple, easy of enforcement, and in accordance with our way of doing things, and would require little or no machinery beyond that already in existence. So run these arguments in Mr. Pinchot's address.*

11. Basic Studies. Since forest lands cover one-fourth the area of the United States, their development and use will become increasingly important as this shortage of forest products develops. This development and use will depend: (1) On the policy of the owner; (2) on the economic conditions which affect values; (3) on the exact silvical knowledge available. This third condition is fundamental, because policy and values are so closely linked with thorough knowledge of growth and silviculture. The study of volumes and growth are important branches of forest research, but all research, direct or indirectly, aims at the solution of the problems underlying forest regulation. To be sure, there must be a balance between policy, economic conditions, and the results of research; but research is often so *all important* a problem that it may come first. At present there is a tendency to give economics too much prominence. Shall timber sales sway absolutely forest regulation? Or will regulation influence the business of lumbering? This general question must be decided in each case on its merits, but the ideal of forestry is unquestionably to put sound regulation (based on research) first.

12. Curtailment of Production. Recent attempts to curtail normal government timber sales on the Pacific Coast so as to relieve the private owner from competition, are needless and unwise; and yet recently a forester proposed that the regulation of the *private* timber resources in the South to prevent too rapid exhaustion might demand assigning a cut to that region with

* An interesting proposal is made by Roth and enlarged upon by Watson (J. Forestry, Dec., 1921, pp. 817-835, "Sustained Annual Yield as a National Policy of Forestry") to organize and plan for forests cut by any accepted method, but to protect the growing stock by allowing only the cutting of one-third the basal area per forty every twenty years. This would certainly tend to stop forest devastation and prolong the cut but like rigid diameter limit systems is too artificial to be generally applied throughout the country to all types of stand. Watson is, however, on the track when he states (in the article cited above) that: "It has been shown in the previous pages that neither satisfactory fire protection, silviculture, nor a system of taxation of private lands can well be established until the forest properties of the United States, private as well as Federal or State, are brought under a form of continuous production . . . some form of forest regulation is needed . . . in a management fashion."

of forcing some owners there not to cut more than a certain amount. The amount could be gauged by the potential productivity of the soil, and it could be dictated by the future danger of a timber shortage. This is a bold policy, but it indicates how regulation may sway the economic problem of production. With the laying waste of forest lands owing to overcutting, such as taken place in the *Lake States*; how long will it be before soil values can be restored? Unquestionably it will be years, and the expense will be many times the cost of cutting more conservatively in the beginning. This principle is fundamental of good forestry.

Russell* figures the *possible* annual growth from all timber lands in the United States at about the amount now used, but before the *possible* annual growth can be secured, from fifty to a hundred years must elapse. In other words, past overcutting means a hiatus in our *national* sustained yield (see § 1).

Continuous Forest Production. In a broad sense the policy of holding public lands on the basis of continuous forest production means: (1) Stabilizing the lumber industry, (2) the adoption of a true and sound forest policy, (3) a solution of important land and forest labor problems of the country; (4) provision for permanent cheap transportation in the forest. As soon as public lands, both public and private, can be placed on the basis of permanent sustained production, the greatest advance will have been made in national conservation—the first step towards the termination of forest destruction.

Early Western Land Policy and Its Results. Conditions in the West** during the past half century have led away from systematic regulation rather than towards it. First the Government tried to dispose of its land for revenue and railroad development; then for the benefit of settlers, and throughout the application of the public land policy, there were always frauds which involve astounding values in public property. In the West, too, frequently the citizen endeavored to beat the United States, and to see how he could get around the law. The laws, themselves often impractical, encouraged this viewpoint, and there was unbridled exploitation of resources with no regard for the future; (a) in agriculture (where the soil was "cropped"); (b) in land speculation; (c) in forest devastation; (d) in extravagant methods of mining; (e) in illegal fencing; (f) in the free disposal of water-power sites; (g) in survey frauds; (h) in swamp-land frauds; (i) in the profligate disposal of railroad land grants; (j) in homestead commutation.

The Public Lands Commission reported:

"Detailed study of the practical operation of the present land laws, particularly of the desert land and commutation clause of the Homestead Act, shows that their tendency far too often is to bring about land monopoly rather than to multiply small holdings by actual settlers The settler is at a marked disadvantage in comparison with the shrewd business man who aims to acquire large properties. There has been spoliation and illegality due to the weakness in laws, speculation and corruption of petty officials appointed for political reasons."

Russell Watson (J. of F., 1921, pp. 390-393).
Hill, Robert Tudor, "The Public Domain and Democracy" (Columbia University, 1909).

According to Hill,* "The situation seems partially to reduce itself to this:

(1) Exploitation of natural resources has produced waste, and future social interests have been disregarded.

(2) Frauds against individuals and society at large represented by the Government have been encouraged and perpetrated on a large scale, and private and dishonesty has ensued.

(3) Public estate has been used for private interest on a large scale. It takes for social ideals to change. Social disapproval has been extended far enough to prevent the individual from holding himself superior to law." The paragraph number have been inserted to give force to Mr. Hill's conclusions.

Thus, as a background to forest regulation in the West, we have the doctrine of individual liberty, the opening of the public domain to give away natural resources which were fast disappearing.

One of the** troubles with the early western administration was that business principles were needed just as if the public domain were a private estate. When an efficient administration of the National Forests was commenced, misunderstandings of policy and objections to the rules and regulations were prevalent. The mining interests were afraid that they were going to be unable to proceed unmolested and unrestrained, and that they would not get timber at a reasonable cost. The grazing interests were afraid that restricted grazing would mean confiscation of their stock, and before the repeal of the lieu land-selection law, all the public feared that the large owners would denude their land and then exchange it for script. Such objections which were most potent in northern California, found some vent in other parts of the West.*** These fears have been disproven.

15. Effect of Economic Lumbering on Forest Management. A study of the lumber industry by the Forest Service has shown clearly that

"forest conservation is affected by economic conditions in manufactures whose material is wood. Demoralized lumber markets affect the value of timber, the stability of its ownership, the degree to which it is wasted in exploitation, and the possibility of carrying out any far-sighted plan of forest renewals," the need for broad government regulation is all the more important.

According to Greeley, ". . . the main problem of the lumber industry is a financial problem. It is a problem which has grown out of quantities of cheap timber acquired from the public domain."

Greeley shows that the West has a surplus of saw-mills and logging camps, that there has been speculation in timber, that owners have over invested, that mill capacity has been excessive, and there have been poor methods of finance, and low efficiency in manufacture and in salesmanship; that competition has been destructive. And yet unquestionably, as Greeley shows, "the public is vitally interested in the prosperity of the lumber industry."

* Ibid., page 215.

** Woodruff, G. W., "The Disposal of Public Lands." (Proceedings S.A.F., March 10, 1904, page 53.)

*** Potter, Albert F. "Objections to the Forest Reserves in Northern California." (P. S. A. F. Vol. 1, 1904, page 50).

* Greeley, W. B. "Some Public and Economic Aspects of the Lumber Industry" (part 1, Secretary of Agriculture, Report No. 114, 1917).

ns where it is the dominant factor in the economic life of the community." Unquestionably there is need for

more suitable kind of forest ownership the extension of public forest ownership is needed. Private ownership has shown itself ill fitted to the task . . . private coöperation in taxation and fire-protection reasonable public regulation of the handling of private lands will unquestionably find a place in working the problem."

The conclusions are that within the next two decades there will be local timber shortage, hastened by over-production due to the wrong kind of ownership. The answer to all these evils which Greeley has enumerated in study of the lumber industry is unquestionably broad gauge forest regulation, which primarily must be based upon the study of growth because, as study emphasized, without knowledge of the rapidity of timber production on the acre, the regulator of forests has little chance of giving correct answers to the various problems.

The public must coöperate with the private owner to make a regulation of a practical business. There are people today who fear regulation of cutting and the curtailment of lumbering operations and the consequent restriction of economic development. We have simply reached another stage in the management of our national forest wealth,—the obligatory regulation stage,—and *does necessitate some present day sacrifices for increased future benefits.*

According to an unpublished paper by Zon,

another persistent fallacy is that forestry cannot be profitably practiced unless stumpage prices are high enough to raise timber to maturity on a bare tract at a profit after all costs including compound interest. If we are to allow our forests to be converted into deserts and then expect to reclaim them by planting, the chances for having in this country any forests at all, are very slim indeed."

If forests are completely wrecked, it will take a century or so to repair the damage.

According to present estimates, private owners have fifty to sixty years of supply at the present rate of cutting. There is an annual demand of approximately one hundred billion feet a year, forty billion for lumber, sixty billion for ties, poles, fuel, and fencing. To supply such an enormous demand there is need of young age classes to grow the forests of the future. According to Zon,

If all our forests were placed at once on a sustained yield basis, they would absolutely produce the annual supply of wood needed in this country."

But today the lumberman is afraid of regulation. Under present conditions there has been over investment by the lumber industry. Owing to the high cost of capital, the incentive to destroy the forest investment as soon as possible in order to reduce the carrying charges has predominated.

b. Possible Solutions; Restricted Private Control, or Public Ownership?

There are two possible solutions to this problem; control of the private individual, and restriction as to how he shall use his forests, or, ownership by the public. Because of American Democracy the viewpoint that the public should own most of the forests, is, in many ways, logical, but a large proportion of necessity remain in the hands of the individual. Toumey* says,

*Toumey, J. W., Who shall Own the Forests (Yale Review, Oct., 1913, p. 156).

"Can you look forward to the time when at least one-half of our permanent area will be publicly owned? If not, our private forests must come under government control, with prescribed methods of management. Future development in American forestry must be in one or the other of these directions. The writer believes ownership is far more in harmony with American instincts, and more acceptable to the great body of American people."

If the private owner, notwithstanding carrying charges imposed by taxation and interest on his investment, desires to own forest land, and refuses to adopt conservative methods of treatment, what is the solution? With a situation such as this, an ex-appropriation of at least those forests which cover erodible slopes and water-sheds will unquestionably be feasible in the interests of the public. For forests in level country, that are managed as supply forests, perhaps conservation has not advanced far enough in this country to justify at once federal or state control. Time will tell. Fernow, in discussing the control of small owners says:

"The former may be largely left to the free exercise of private enterprise, and will probably be the answer to the regulation problem so far as it touches the small owner; he will not brook control, and so long as he is willing to fight it, probably will have his own way."

Kirkland** argues that public ownership is not necessary even to secure a sustained annual yield; that it would be practicable to put the forest industry on a permanent producing basis by establishing a central association of American forest industries which should classify, finance, organize, and standardize the business of the members, and most important of all regulate output and prices.

"The only effective maintenance of price must be one through limitation of quantity placed on the market. The only sound limitation of the amount to be marketed annually is that imposed by what this resource will produce continuously. Bad as that forestry is which overcuts any given producing unit, that which undercuts is still worse because it neither furnishes revenue to the owner nor supplies the consumer with product."

Fernow for one does not believe in the practicability of Kirkland's solution, nor does the writer, unless this suggested association of private forest owners is under National control—an association of private owners and producers operating under the guidance of the Forest Service would undoubtedly work efficiently and may be the solution of preventing the present devastation.

17. Policy and Definition of Sustained Yield. Granting that there must be public control of forests, we have then to answer the question, Shall the cut be according to the principle of a sustained yield or shall economic conditions and fiscal expediency gain the ascendancy in the decision as to "How much must be cut"?

Sustained yield is the yield or cut of timber from a forest which is managed

* Fernow, B. E., *Economics of Forestry*, New York (5th Edition, p. 271).

** Kirkland, Bert T., *Continuous Forest Production of Privately Owned Timberland as a solution of the Economic Difficulties of the Lumber Industry*. (*Journal of Forestry*, Vol. XV, 1917, pp. 15-64.)

ch a way as to permit the removal of an approximately equal volume of timber annually or periodically.

is argued* that a sustained annual yield gives the best social results, the investment, the safest management. In Europe there can be no question that forest workers, with permanent work in their local valleys, are better off than they are in temporary logging camps of the United States.

Comparison with Conditions in France. According to Huffel, the foremost authority,** the arguments in favor of an *annual* yield are summarized as follows: wood products will not stand long distance transportation so that it is better to go to local markets which are often dependent upon an annual wood supply for their prosperity; a sustained cut is better for lumberjacks and teamsters as well as for wood-using industries; an annual revenue is best for the owner of forests; it is of less benefit to the state but a necessity for many communes and individuals. This annual yield should not be too unequal because of the drawbacks to labor and local industries dependent upon a supply of wood. For this reason and on account of the dictates of silviculture, increases or decreases in growing stock should be gradual. But the difference between the intensive forests of France, for example, and the working circle on the Pacific Coast is so great that it is very confusing. In the one case (France) a working plan may regulate a working circle of but a few thousand acres; in the other case perhaps it takes two hundred thousand acres or more to form a circle that will yield a large enough cut to justify the maintenance of the local timber-using mills and industries. In France, for example, the valley is tributary to a small group of sawmills; here the unit of sustained yield is smaller, simply because of its more advanced stage of forest development, and because of the local labor and market conditions which favor an annual cut, and an annual cut convenient to the homes of the workers. There does not find in France the large scale railroad logging of the United States. Good roads permit easy hauling at any point; each little hamlet has its constant local wood and timber needs; the social and economic conditions are absolutely different, and therefore working plans and regulation in the two countries must be built on different lines. Often the principles are the same, but the application of methods in the Western United States must be broader, and must be changed to conform with different problems that are to be solved. Perhaps in some localities on National Forests fire protection must come first, and strict regulation of timber must be retarded for another decade or two. Perhaps for a time the pressure for timber sales may lead forest administrators to adopt a policy of giving precedence to timber sales examinations over areas which should be cruised for management reasons; whether due to appropriations or not, this is unfortunate and is now being modified on some National Forests; but under existing conditions may for a short time continue to be a necessary economic result. Without permanent efficient transportation owned by the forest proprietor the present temporary large scale logging camp, uprooted when a locality is cut, is a natural consequence of economic conditions. The forest workers must suffer; the social evils attendant to a shifting population are proverbial; what is more familiar than the wastage and extravagance after a winter's work in the woods! In the Eastern United States after two centuries of logging these conditions still exist because large scale logging is so customary. With *permanent* sawmill industries and local workers (with families) different social conditions would come, logically and naturally as in Europe.

9. Financial Aspect of a Sustained Yield. Usually investments yield semi-annual or quarterly returns and recently attempts have been made to

Kirkland, Bert T., The Need of Working Plans on National Forests and the Policies Which Should Be Embodied in Them (P. S. A. F. Vol. X, 1915, pp. 341-371).

* Huffel, G., already cited, pp. 9-12.

popularize monthly dividends. To meet the minimum demand for an annual income sustained yield production of forests is necessary. The recent studies of the lumber industry* indicate that better financial results (because of production under existing methods of wrecking the forest property) can be brought about only by,

"A more stable kind of forest ownership, divorced from manufacture to a large degree than now, must come about before the ills of the lumber business can be permanently cured . . . Private ownership has shown itself ill-fitted to the task, at least in the larger forest regions."

Legitimate demands for timber must be met, but forced sales** should be discouraged. Then too, it is generally recognized that present methods of taxation*** are an incentive to over-production, since the operator must create a demand for his timber rather than to hold it for permanent production. It is interesting to bear in mind that a 15 per cent tax on the yield of private stands would yield about the same revenue on the Pacific Coast, as is at present received by the communities from the 25 per cent tax on current production of all timber cut from the National Forests.

20. Sustained Yield on Public Forests. Even as early as 1905 the government has idealized a sustained yield. In an early working plan* for private lands it was argued:

"The object should be to get a sustained yield from as small an area as possible provided this does not materially interfere with, or increase the cost of present operations. The smaller the area the smaller the invested capital and the yearly taxes and in the long run this means the saving of a considerable sum of money."

The public naturally expects the National Forests to be models of permanent forest production. Why then has not a sustained yield management been adopted? The answer** is:

(1) That there are physical limitations that are now insurmountable owing to inaccessibility and lack of transportation. "*** . . . primary transportation must precede any kind of forest management."

(2) Competition with private stumpage more conveniently located would necessarily reduce prices below the danger point if national timber sales had to be forced. "Sustained annual yield presupposes a sustained market," which is rarely available.

(3) The National Forests are a great resource which cannot be depreciated or forced on a market which is glutted with cheap private stumpage. Yet as is pointed out ". . . management with or without the sustained yield principle is totally unrelated to the policy followed in pricing stumpage . . .," according to the appraisal system now in force on National Forests.

* Greeley, W. B., *Studies of the Lumber Industry, Part I* (U. S. Dept. of Agriculture Report No. 114, 1917, p. 4-5).

** Ibid., page 95.

*** Hutton, G. W. and Hapham, E. E., *Forest Taxation as a Factor in Forest Management*. (P. S. A. F. Volume 13, 1916, pp. 50.)

* Chapman, C. S., *A Working Plan for Forest Lands in Berkeley County, S. C.* (Bureau of Forestry, Bulletin 1905, p. 50).

** Greeley, W. B., *National Forest Sales on the Pacific Coast* (P. S. A. F. Vol. 1, pp. 42-50).

*** Greeley, W. B., *Working Plans on National Forests* (P. S. A. F. Vol. XI, 84-85).

more* argued that sustained yield is not necessary "where the community forming natural market for the timber is not dependent on National Forest material,—that here material can be brought in from the outside as cheaply as it can be produced locally,— . . . where there is no local market for the timber, . . . and where . . . the possible annual sustained yield is too small to warrant the building up of community dependent solely on lumbering."

The writer agrees that during the development stage of forest management there will be innumerable instances where a sustained yield (either annual or periodic) will be at present out of the question for practical reasons. One must bear in mind that after the first few periods there can still be *permanent production* even if a strict sustained yield does not commence until after the improvement fellings have removed the overmature and diseased timber. Virgin forests often good silviculture and a theoretical sustained yield during the first rotation do not go hand in hand. One reason why there has been so much divergence of argument regarding sustained yield is that it has been idealized and its practical limitations** not sufficiently appraised.

Sustained Yield Objectives and Difficulties in Practice. The policy of the owner and his objective in managing the forest is always the first consideration in forestry, and will ordinarily determine the whole course of forest management. The private owner may put financial returns first. The public owner may not desire to manage the forest from a strict dollars and cents standpoint, but may wish to preserve the stand, so as to conserve an important water supply, or keep the forest as a recreation ground for the public. In any event, the forest resource must be maintained in a state of maximum and continuous production. Hence the principle of sustained yield enters in, because the ideal of management is the maintenance of the best possible continuous yield. A continuous yield is just as important in forestry as in any other kind of business. It is more difficult in forestry than in other forms of business, because of the length of time required for crop production. These difficulties necessitate special plans to accomplish a sustained yield, which can rarely be attained during the initial years of management.

Summary of Limitations on a Sustained Yield Policy. In arguing for sustained yield one must not overlook certain limitations; the principle of sustained yield may be correct but it may not be practicable for a number of reasons:

- 1) It is fundamental that the land must be chiefly valuable for forest purposes. Obviously it would be shortsighted to plan for permanent production on any area, without first inquiring whether the soil itself was *now* chiefly valuable for agriculture.
- 2) Transportation facilities may not permit. If there is poor transportation, this may prove a practicable argument towards cutting more than the amount warranted on the basis of permanent production, in order to meet large and temporary transportation charges incident to the construction of expensive logging railways. Such a situation is unfortunate.

*Moore, Barrington, *Methods for Regulating the Cut on National Forests* (P. S. A. F., Vol. VII, 1912, p. 12).

**Woolsey, T. S., Jr., *Forest Service Silviculture Plans* (P. S. A. F., Vol. XI, 1916, pp. 15-16).

(3) The market for timber products may be insufficient to utilize the entire amount or the quality of timber produced. Perhaps there are accessible and readily available bodies of timber which are being wrecked, in order that the soil may be used for agriculture, which will for the time being, compete with the owner who desires ultimately to adopt the sustained yield principle. This condition is typical of extensive conditions where a final land classification has not been made, and where economic conditions governing the sale of forest products are unsettled.

(4) The silvicultural needs of a forest may necessitate the rapid removal of mature timber. Perhaps large areas of mature age classes demand the installation of mills whose capacity cannot possibly be supplied when once the excess growing stock has been reduced to normal.

(5) The demand for timber products may fluctuate according to the development of cities, mines, or other chance local development, with profitable export of only higher grades of lumber.

(6) Acts of Providence will always exert an influence against the successful adoption of a sustained yield. Fire, insect attacks, disease, windfall (and perhaps war) may tend to derange the application of an exact sustained yield. For example, even in regulated forests abroad the variation in the annual yield is considerable. In the Forest* of Retz (France) the cut in 1863 was fixed at 987,671 cubic feet; in 1871, 1,218,055; in 1887, 996,535; in 1896, 1,241,736, and in 1902, 1,014,319. Such variations in a regulated forest under intensive economic demand indicates how much greater variations will be under American conditions.

(7) Of less importance, but withal to be reckoned with, is the personal factor in forest administration. From forest history we know that the tendency of administrators is to overcut or undercut. Some administrators (British India is an example) desire to make a good financial showing; consequently, they may be led to cut more than the forest produces, unless they are restrained by working plans based on a knowledge of forest production. Other administrators (as evidenced by France) undercut the forest, sometimes with poor results, because it means the accumulation of over-mature timber and consequently increased danger from disease, windfall, insect infestations. Changes in regeneration methods may disarrange for the time being the regulated cut.

(8) One of the greatest obstacles to a sustained yield is the character of the forest itself; the fact that so far the cut has generally been from virgin forests of mixed species, instead of from second growth or grown as even-aged stands free from suppression. (See paragraph 108.)

The sustained yield management ideal is thus something to steer by; it is not so unattainable as the normal forest, but nevertheless there are many pitfalls before it can be reached. The administrator and student of forest production must bear in mind that permanent production is safeguarded only by frankly acknowledging a sustained yield policy for working circles of reasonable proportion. The working plans officer must be enough of an idealist to combat the every day arguments of the opportunist administrator, who desires to give practicable considerations too great weight when solving the vital problem of permanent forest production.

23. Quiz. What will future forest development depend upon?

What is an important aim of research?

Should preference be given regulation aims or the dictates of local business requirements?

Discuss permanent forest production and conservation.

* Fisher, W. R. (*Quarterly Journal of Forestry*, 1910, pp. 285-286).

- Why do past methods of disposing of the public domain in the West make conservation management difficult?
- What were early objections to the national forests?
- What is the matter with the lumber industry?
- How can it be improved by regulation?
- What are the solutions of national regulation of timber cutting?
- What does Kirkland suggest? Is it possible?
- Discuss sustained yield and the worker, the investor, the forest, taxation.
- Why cannot a sustained yield management be adapted at once on national forests?
- When is it claimed to be unnecessary?
- Summarize the sustained yield problem—advantages and limitations.
- How exact can an annual sustained yield be: (a) in France? (b) on our national forests?
- What are some of the difficulties in the United States?

CHAPTER III

MANAGEMENT AND ADMINISTRATIVE SUBDIVISIONS

24. Definition of and Size of Subdivisions. In order to intelligently tematize the location of cuttings at the proper time, and in order to determine the area of forest to be cut over and volume of product to be removed, land must be suitably subdivided into practicable *subdivisions* which are defined as *a larger or smaller part of a forest property segregated with a view to making units for purposes of administration, protection, organization, and management*. The size of the subdivisions will depend on the intensiveness of management and administration. Where the conditions are intensive, as in New England woodlots, the size of subdivisions will obviously be much smaller than on the Pacific Coast. In New England the cordwood, poles, posts, or ties are usually marketed by the owner. This is facilitated by established wagon roads. Thus if desired small tracts can be managed on a sustained yield basis under one working plan. On the Pacific Coast conditions are essentially different because railroad marketing of saw timber demands a large area of timber so that the annual cut may be sufficient to maintain the investment. Still another factor—the progress of silviculture—enters into the problem. With virgin forests, management subdivisions will always be larger than where silviculture has been intensified. In the early years of management there will be fewer distinctions in methods of cutting and in rotations. It stands to reason that the size of administrative subdivisions will vary in like manner. The forest in Europe under the control of one man may be limited to 10,000 acres because of the detail incident to its administration. The typical national forest of the Western United States today perhaps averages a third of a million acres and is as efficiently managed in a relative sense as is the 10,000 acre tract in Europe. There may be frequent thinnings, but few sales (and these are centralized), and no forestation; instead the manager's time is centered on fire protection, grazing control, and the broad problems of administration. It is important to grasp clearly the differences in the conditions which indicate intensive or extensive subdivisions, which are of two kinds: (1) Management and (2) Administrative.

25. Definition of Management Subdivisions. Management subdivisions aim at the orderly location of all data on forest resources so that this knowledge can be applied to all timber operations within the forest and the results recorded so as to preserve an accurate history of past cutting. These subdivisions are divided into working groups and working circles for the regulation of yield.

Working group may be defined as an organization or working plan unit, comprising an aggregate of compartments or stands to be managed under the same silvicultural system and rotation. (Syn: working block; working section; management class. G., Betriebsklasse. F., Serie D'Exploitation.)

Working circle may be defined as an economic forest area managed under

It may or may not coincide with the administrative unit or with the working plan. (Syn: working plan unit, working figure. G., Wirtschaftsganzes.)

There appears to be more variation in the use of words for working-group and working circle than with other terms of current use in regulation. According to Schlich,* the working section (corresponding to working-group) is "a number of components . . . grouped together into cutting series, . . . a number of the latter is a working section." Moreover, according to the same author, "if a working section (our working circle) "consists of only one series of age classes, it is identical with a working section" (our working group). A working circle (our working section) is, according to Schlich, an "area which is managed under the provisions of one and the same working plan." Other terms have also been introduced. Recknagel** used in his first edition the term "working figure" for "that unit which is managed with the idea of a sustained yield." He stated "But in America the unit of regulation, the working figure, must be the market unit." To simplify the unit of regulation he omits the distinction between working group and working unit. Recknagel*** uses working section for group and does not distinguish working circle as a separate term.

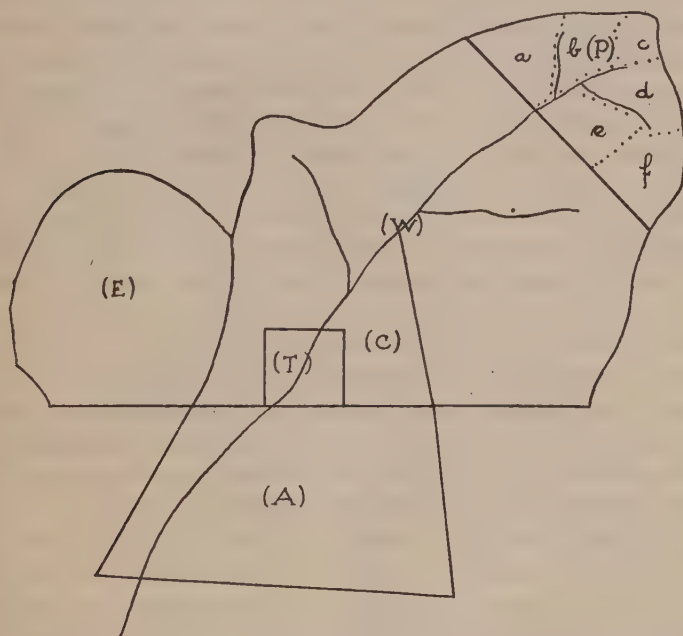


Fig. 2.—Diagrammatic Sketch Map Illustrating the Distinction between Working Group and Working Circle (Syn., Working Unit).

3. Discussion of Management Subdivisions. The distinction between working group and working circle is illustrated by Fig. 2.

There is represented a central town, with established sawmills and associated industries, surrounded on the south by (A) agricultural land, on the

Schlich, Wm., *Manual of Forestry*, Vol. III, 1911, pp. 273-285.

Recknagel, A. B., *The Theory and Practice of Working Plans*, 1913, p. 20, p. 33.

* Roth, Filibert, *Forest Regulation* (Vol. I, *Michigan Manual of Forestry*, pp. 1-20).

west by a pure (E) Englemann spruce forest managed on an eighty-year rotation for paper pulp, on the north and north-east by a large watershed stocked with (W) western yellow pine, where clear cutting is followed by planting on a one hundred and twenty-year rotation. Directly to the north-east of the town is a simple (C) coppice of scrub oak managed on a two-year rotation; further up on the mountain is a city watershed, held clear as (P) protection forest with natural regeneration. The rotation here is one hundred and fifty years, and the mixed conifer stand is cut over by selection fellings on a cutting cycle of twenty-five years. In the case of the local industries of the (T) town were entirely dependent upon a sustained yield from the combined watersheds. Under these circumstances a separate working group would be established for each of the four stands (E. C. W. P.) since these four stands are tributary to this one town, it would be entirely practicable to have *one* working circle include the four working groups. On the other hand, instead of four different stands with four different systems of management and varying rotations, the entire area had consisted of western yellow pine with a hundred and twenty-year rotation, followed by clear cutting and planting, *but one working group would have been established*, this would have coincided exactly with the working circle; whereas under the conditions cited in Fig. 2, there are four working groups, because of varying types, silvicultural system and rotation. A further complication might have been introduced had the area (W) been so large that it could not have been conveniently handled under one working group. In such a case mere size might have dictated the formation of additional groups. It is therefore important to bear in mind that the working group is a smaller and narrower management (silvicultural) subdivision than the working circle. The working group is determined by type, *silvicultural system*, rotation, size, while the working circle would be determined more by transportation, market, and business and not by silviculture. Fernow naturally considers "working circle" the broader term, judging the aggregation of stands from the administrative yield and market point of view, and "working group" the narrower term, based mainly on *silvicultural management* as a unit.

27. Factors that Justify Formation of Working Groups. The formation of separate working groups may thus be dictated by the following factors: (1) forest type, (2) silvicultural system, (3) rotation, and (4) size of area.

(1) Forest type. Types differ according to the kind of product yielded, the silvicultural system of cutting and reproduction. They may demand a different rotation; therefore, whenever types cover such a large area or differ sharply in products yielded, rotation, method of cutting or reproduction, that they cannot be worked as one group for the regulation of the yield, it is necessary to establish different working groups.

(2) Silvicultural system. Suppose that on one watershed there is clear cutting followed by planting, while on another the forest of yellow pine is managed by selection cutting; here separate working groups would be indicated. If these stands could be managed under the same silvicultural system, probably no distinction into two working groups need be made.

3) Rotation. Where two entirely different rotations are necessary, separate working groups must be established. This is not always the case, however, because in a mixed stand, frequently species with different rotations managed under an average rotation in but one working group. But if types were entirely separate with widely varying rotations, then different working groups would be essential.

4) Size of area. A single working group must have eventually, if it is cut, a complete series of age classes, and these age classes must be as full as is consistent with economy in logging, so as to reduce the danger from fire, windfall, fungus and insect damage. It is a fundamental maxim in silviculture that large even-aged stands endanger the forest; therefore in a very large working group, excessively large age classes could not be divided if a clear cutting system were practised. Consequently, more than one working group might be necessary in order to reduce the size of the age classes.

8. **Working Circles.** The working circle (as contrasted with working group) is, in theory at least, dependent chiefly on the market, but under modern methods of rail transportation so typical of American lumbering, the market may not be the primary factor except in the case of small local market units where rail transportation does not enter into the problem. Rail markets draw from a wide territory, and therefore a working circle may, under exceptional circumstances, be composed of several forests so far as the market is concerned, but restricted in size because of administrative or management grounds. Ideal conditions for a working circle, where a sustained yield is desired, consist of a complete market, complete transportation facilities of a permanent character, such as drivable streams, or a permanent system of forest roads. If temporary roads, railroads, or flumes must be built by the operator and paid for by him from the operation of cutting the timber, then these apparently unavoidable economic conditions make the attempt to regulate the annual cut more perplexing. In some cases it might happen that there was not enough timber locally to permit of a sustained yield until later rotations, and it must therefore be cut off rapidly in order to make a practical logging chance. An economic woods operation would be secured at the expense of the sustained yield—an objectionable feature.

Under extensive conditions such as exist on the Pacific Coast, working circles are laid out in territory logically tributary to manufacturing centers by existing or possible transportation. This basis, under these conditions, fits in with the objective of a permanent industrial center and should have more weight than topographic or administrative conditions, which are here of secondary importance. Another problem met with under extensive conditions is whether to take into consideration land under private ownership when establishing national forest working circles. The policy should unquestionably be to give due consideration to the private timber which will probably come into the market, since this will help to maintain the industrial center just as easily as the cutting of public stumpage. Allowance on the other hand must be made for timber land, which may be chiefly valuable for other purposes, since such areas will contribute to the support of the economic working circle after the first crop of timber is removed.

29. **Policy of Small or Large Working Circles.** Really effective regulation and a future sustained yield can best be obtained by securing reasonable small working circles (working plan units) today. Very large working circles, such as have been planned for some of our western forests, will include the possibility of moderate sized local sawmill industries, because virgin stands are cut heavily on a watershed (with the idea of moving operations to another watershed of the working circle later on), there will be no local merchantable timber for cutting after several decades. Where possible the plan advocated by Wolff* of having working circles coincide with natural main drainage areas is certainly logical, the intensification of administration, the fire danger, the bodies of overmature timber in immediate need of disposal and the sale of some of the less accessible timber are problems which can be adjusted and overcome. Small working circles will encourage permanent local industries, stable labor conditions, more permanent improvements, diversification of sales, better silviculture and protection. It is "a safe conservative course"; and the development and maintenance of logging communities is certainly desirable.

30. **Definitions of Block, Compartment and Lot.** To build up suitable working groups and working circles it is convenient to first divide the forest area into smaller subdivisions in keeping with the intensiveness or extensiveness of management. The smaller the division, the easier it will be in a few years to segregate management data according to new and more intensive lines made necessary by a change in economic conditions.

Since forest regulation is the arrangement of operations as to place, time and quantity, subdivisions are for the purpose of making convenient and possible the location of all operations, as follows:

(1) On the ground, so that operations can be conveniently conducted in the forest.

(2) In the office, in order that records may be systematized by tabulations or by means of maps or graphics; these essential records include (a) the inventory of estimates and (b) the record of future operations.

In American forest regulation three subdivisions may be distinguished:

(1) *Block*—A major division of the working circle, intermediate in size between the working circle and a compartment. A block is usually based on topography and comprises a main logging unit or group usually based on topography and comprises a main logging unit or group of logging units. A single block may contain many thousand acres.

(2) *Compartment*—An organization unit or small artificial subdivision for purposes of location, administration, and silvicultural operation. (G., Abtheilung, Jagen (Prussia). F. Parcellen.)

(3) *Lot*—A small silvicultural subdivision of a compartment, differing in composition, age, or character, requiring different treatment from the main body of the compartment; temporary if due to accidental, permanent if due to natural conditions. (Synonyms: subcompartment. G., Unterabteilung, Abtheilung (Prussia).)

* Wolff, M. H. (Journal of Forestry, 1920, pp. 486-497).

r. **Discussion of Block, Compartment and Lot.*** In figure 2 (P. W. C.) would probably form one block including the entire watershed but excluding townsites (T). Area (P) would be divided into compartments a, b, c, d, e, as indicated by dotted lines. The lots would probably not be necessary for protection forest.

(1) The boundaries of the block will ordinarily be topographic features such as watersheds, where the block would correspond to the logging unit rather than artificial subdivisions such as townships. The block should assist in the general location and classification of estimates and forest descriptions, but is for larger areas than for compartments. Whether the topographic boundary will be a stream or ridge will depend on the local method of logging. If the block is based on natural logging units, the estimates will be convenient for small timber sales. If larger sales, comprising many thousands of acres, must be made because of market conditions, the estimates of a number of blocks can be conveniently grouped where each block corresponds to a logging unit.

Care should be taken to clearly distinguish block and working group since the two may frequently coincide. The working circle may even be identical with the working group and block if the area under a sustained yield in a working plan happens to have the same boundaries as the group or block.

(2) The compartment for some time to come will be the smallest permanent subdivision in the West with boundaries clearly marked. These boundaries may be artificial survey lines (corresponding to the western section lines), rods, or preferably topographic features, such as ridge crests or streams. In our western mountains compartments are really small secondary logging units. The formation of compartment lines, *especially in highly intensive management* should, if possible, conform to type, broad lines of quality and age classes. Where compartments can be made to include uniform quality, type and age, it is obviously an advantage to do so, but age, type or uniformity of land cannot be the governing factor. In the United States, compartments in surveyed fairly level country will ordinarily be six hundred and forty acres, and in unsurveyed country considerably larger *depending on the topography*. The size must depend finally on the intensiveness of management. In New England the compartment may be less than one hundred acres.

(3) The lot (often termed sub-compartment) is always a subdivision of a compartment, coinciding with distinct stands or descriptive unit. Since compartments cannot recognize differences in age or quality, the lot may be mapped and described separately if intensiveness of management justifies. Boundaries are usually not permanently marked in the field but even under extensive conditions existing in the Western United States, the lot may be justified in level country (except in mere protection working groups) because of the ease of recording intensive estimates by 40-acre subdivisions. As far as practicable the compartment and not the lot should be the unit

The term lot, adopted by the S. A. F. Terminology Committee in preference to the English term sub-compartment, should not be confused with the local use of "lot" in New England and in government surveys in the West.

of description in extensive timber surveys. The separation into lots be dictated by a change in quality and type, provided this will not necessitate dividing the forest into such small units as to be impracticable of description or age classes, if distinct enough to map. The lot as a silvicultural subdivision without demarcated boundaries will always be of value as an internal unit for timber surveys. In New England the lot may be separated into forest.

32. Definition of Administrative Subdivisions. Administrative subdivisions are district, forest, ranger district or range, patrol district or beat. These are defined as follows:

District—Generically, any administrative unit; specifically, an aggregate of administrative units or forests for control and inspection purposes.

Forest—An administrative unit, as national forest, state forest, or municipal forest.

Ranger District or Range—Part of a forest, an executive unit under care of a ranger.

Patrol District or Beat—An executive unit for protective purposes, under guard or patrol.

Administrative subdivisions thus comprise the entire system of national forests, districts of forests, one forest, a ranger district within the forest or the beat within the guard within a ranger district.

33. Discussion of Administrative Subdivisions. Administrative subdivisions are made to facilitate administration rather than the regulation of yield and forest management. The entire system of national forests may be distinguished from other public lands, or from forests managed under a separate bureau or department. For example, Indian forests, which are managed for the benefit of the Indians, may be segregated from national forests, or state forests. For convenience of administration these national forests have been divided into administrative districts* in order to facilitate the administrative control of the individual forests under supervisors. Each district is under the direction of a district forester assisted by a staff organization, divided throughout the United States according to lines of work, such as silviculture, operations on lands, and grazing. The forest is a distinct or connected unit or aggregate of units under a forest supervisor, who has immediate direction of the administration** under the direction of the district office. The forest is divided into ranger districts, which are in charge of a district ranger. Where necessary to facilitate administration or protection, the ranger district may be divided into beats, each in charge of a guard.

34. Quiz. Define subdivision.

What does the size of subdivisions depend upon?

What kinds of subdivision are there?

* For a discussion of administrative organization problems the student is referred to *Forestry Quarterly*, Vol. XIV, pp. 188-236, Forest Service Revenue and Organization by T. S. Woolsey, Jr.

** It will be useful to give the student definite acreage figures on administrative divisions for Western and Eastern conditions.

- What are management subdivisions?
- Define working group, and working circle.
- What is the distinction?
- When do working group and working circle coincide?
- What determines working groups?
- Discuss how working groups are affected by type, silvicultural system, rotation, size, etc.
- What determines working circle?
- Define lot, compartment, and block. Discuss boundaries, size, value, and distinctions of these three units.
- How does block differ from working group? from working circle?
- When would they coincide?
- What effect will topography have on compartments and working circles in the West?
- What are administrative subdivisions?
- When would a guard's beat correspond to a block and to a working group?

CHAPTER IV

ROTATIONS—TECHNICAL, SILVICULTURAL, AND ECONOMIC

35. Definitions of Rotation (and Felling Age). *By rotation is meant predetermined time or period during which it is intended to cut over a working group; the predetermined approximate felling age of the stands. Rotation refers to the forest as a whole and is usually expressed not by a definite year, but to the nearest decade. Felling age refers to the actual age of the stand when it is felled.*

The length of rotations depend partly on the object of the owner and also determined by technical, silvicultural, economic, or financial considerations as limited by silvicultural possibilities. According to Fernow a rotation is "the time through which the crop is allowed to grow normally until it is harvested and reproduced."

The view-point in India, as expressed by D'Arcy,* is contrary to the European conception of rotation (except in selection forests in France), namely, ".....the exploitable age of a forest crop is the age at which the individual trees furnish the kind of produce most wanted."

According to Endres,**

"By rotation period or rotation is meant that time which elapses, under normal conditions, between the planting and the utilization of a stand. In the case of the working group the rotation is the average time of growing merchantable material which is the fundamental consideration in working plan calculations."

Variations from the normal may be due to unusual silvicultural, financial, or economic conditions.

36. Not to be Confused with Cutting Cycle. Rotation is not to be confused with cutting-cycle in selection forests, which is the period elapsed between cuts on the same area. Obviously in selection forests the length of the cutting cycle has an important bearing on the amount removed, and the frequency of cut also has a direct bearing on the amount that is removed through decay; consequently, there is a tendency with intensive management to short cutting cycles of from five to eighteen years. With extensive management longer cutting cycles are at present unavoidable. In Oregon where yellow pine a cutting cycle of 50 to 60 years has been tentatively adopted, this will be decreased when the market and permanent transportation facilities are established. A cutting cycle of 100 years for western yellow pine in Arizona certainly must be reduced as soon as possible. In France*** under normal intensive conditions the cutting cycle is five to eight years; under intensive conditions, nine to eighteen years, and rarely more than this.

* D'Arcy, W. E., *Preparation of Forest Working Plans in India*, Calcutta, 1898, 2nd Edition.

** Endres, pp. 220-221.

*** Woolsey, T. S., Jr., *Studies in French Forestry*, Chapter IX, John Wiley and Sons, 1920.

ng cycle* is usually a sub-multiple of the rotation; obviously the longer cutting cycle, the greater the cut.

Conception of Length of Rotation. The tendency is to have too low an idea of what length of rotation means: for example, if five-year-old transplants are used for a plantation (after clear cutting) which is allowed to grow one hundred years, the rotation in this case would be one hundred years (the length of time the forest soil is used) and not one hundred and five, the felling age, that is the age of the trees, since the time the transplants spent in the nursery would be omitted in the calculation of the rotation. Yet it is of course recognized that the length of the rotation is shortened by the use of well formed transplants simply because the stand matures sooner. Early frequent and early thinnings are of the utmost importance in carrying out the necessary rotation because with thinnings the stand will mature earlier than if left unthinned. Efficient thinnings not only enable the forester to grow timber of a specified size in fewer years, but they increase seed production and promote earlier seed crops; they decrease the date of the termination of mean annual growth, and, as Endres puts it,

the greatest benefit is felt where the highest soil rent is maintained It is noted that large, early yields produce large soil rent and vice versa A stand has been thinned up to the "n" year will have higher value than one that has not been thinned."

It must be born in mind that while the forest as a whole may be managed according to specified rotations yet individual stands may be cut before or after the rotation age because of accidents, market conditions, etc. Still another point, worthy of emphasis, is that it is usually sufficient if the rotation is approximately established to the nearest decade; it is splitting hairs to figure to the exact year when computing the rotation.

Biolley in a recent treatise cautions against placing too much stress on exactness in considering rotations.

... they persist in confusing the age and the size of trees The age or size is only one of the factors of the result sought for (and not the principal one) The other factors are: the suitable rôle for each tree and especially the "savoir-faire" of the silviculturalist, the quality of treatment by means of which he creates and improves these factors The result sought for can only be a function. The age is only an accessory."

What Biolley** wants is really a flexible rotation to be modified by the silviculturalist so as to give the best possible production according to the demands of each group of trees, site, or local conditions of stand. "The Gurnaud consists above all in experimenting with the treatment." His ideas are based on too intensive a treatment to be applicable for the United States, and it may often be unwise to give the officer in charge of a stand too much leeway. Regulation implies systematized control.

Refer to the discussion of cutting cycles in "Studies in French Forestry," already cited, pp. 226-228; also see chapter X, Part II of this volume for a more detailed discussion of cutting cycles.

L'Aménagement des Forêts par la Méthode Expérimentale et Spécialement La Méthode du Contrôle. Attinger Frères, Paris, par H. E. Biolley, 1920, p. 15.

According to Blascheck,* in India economic conditions necessitate annual felling area; an average tree best suited to the objects of the management; sufficiently heavy fellings to insure regeneration; and, of less importance, a felling cycle which shall be a sub-multiple of the rotation.

38. Basic Policy for Rotations. One of the chief difficulties in computing rotations (and especially *financial* rotations) is that the forester must present statistics or the *trend* of present statistics for calculations which pretend to answer management problems on the basis of unknown or roughly approximated conditions a half century or a century hence—obviously impossible to fathom. But the proper regulation viewpoint is that the problem should be solved for the present on the basis of the best available present data with the assumption that when the working plan is systematically revised, these calculations will be recomputed and brought up to date. In fact that a revised and altered answer to the rotation problem will be certain is no reason for not doing our best with available statistics. As a matter of policy it is often safe to also estimate future conditions, based on the trend of economic conditions, rather than to follow blindly present stump prices, present cost values, present current interest rates and market requirements for forest products. The best regulation implies some attempt at fathoming the future. We know from past history that forest conditions will change; therefore to follow *blindly* present conditions, we will arrive at the least accurate predictions. There is a *via media* between following today's data on the one hand and on the other of making unwarranted guesses at the future. Moreover we must realize that our calculations are at best approximations and therefore the minutiae may often be omitted with propriety. American foresters, in striving for details, are apt to lose sight of the goal.

39. Mean Rotations for an Entire Stand. The forester must (in the United States) distinguish in intensive regulation (as for example in parts of New England) between the rotation for a particular stand and the rotation for a working group which is composed of a number of stands of varying quality, but in the West (in Northern Arizona for example) a rough general average rotation for portions of an entire region, will usually be a sufficiently close approximation for conditions prevalent while National Forests are being organized. Even in a selection forest such as Chamonix the French prescribe one typical rotation for Norway spruce and larch based on a rough proportion of the length of time it takes to grow the two species, and weighted according to the aggregate volume present. This rightly emphasized the futility of minute mathematical calculations for the solution of a problem which demands an approximate answer.

40. Kinds of Rotations. The following kinds of rotations are of value in the United States and are listed in the order of extensiveness:

- (1) Technical, maximum of material for a certain purpose and size.
- (2) Silvicultural, based on limitations of species to reproduce or to resist decay.

* Blascheck, A. D., "The True Selection System" (Indian Forester, 1913, pp. 427-

Economic, maximum average volume production gauged by culmination of mean annual growth of stands.

Financial, divided into:

a. Maximum forest rent or highest mean annual net money income (regarding interest).

b. Maximum soil rent or highest returns per dollar invested (with sound interest).

Definition and Discussion of Technical Rotations. *Technical rotations apt to produce the maximum of material suitable for a certain purpose and given size, such as railroad ties, mine-timbers, or saw-logs.*

Technical rotations in the United States are of more than mere historical interest. A technical rotation, especially under conditions existing today in the West, might give the correct answer. Take the case of a watershed which is most suitable for producing railroad ties, because railroad ties alone can be floated down a drivable stream, the sole means of transport; here technical rotation based on the length of time it took to grow ties of given dimensions, is clearly indicated. The exact length, in this case, would depend on the most suitable period for growing the quality of tie which yielded the best net return on the investment, not taking into consideration compound interest charges* unless the data for financial calculations were available.

French Government selection forests technical rotations are usually chosen so as to produce the kind of material most in demand by the public, to support local industries vital to the economic life of the locality. This kind of rotation, under the conditions existing in the Vosges, Jura, or Alps, where large sized saw logs are required, has been severely criticised by German foresters because of the financial losses usually involved; with public forests it is usually better policy to put national needs above narrow conceptions of financial gain; so it is held that for National Forests French policy is fully justified. A somewhat broader German viewpoint, expressed by Endres,* is as follows:

"Were we to apply the technical rotations to even-aged high forests, producing mainly timber, great financial losses would take place. However the policy of bringing out a mixture of species in order to meet market requirements or demands is presently correct It is in keeping with sound forestry because it also maintains soil fertility The technical rotation may also be used by the state for social and political reasons but the technical rotation can only be recognized if production costs are of no consequence to the owner."

Illustrations of Technical Rotations. One of the earliest examples of technical rotations, for use on national forests, is that for western yellow pine, established in 1864. According to Woolsey,**

"If only timber of the lower grades is produced, export shipments will suffer. It is therefore particularly essential, on account of the long hauls and consequent heavy freight rates, that a fair proportion of higher grades be supplied The best rotation cannot be predicted until after regulated cutting Tentatively, a rotation of 200 years is recommended."

*Corstian, C. F., Manuscript Report, files of Forest Service, District III.

**Woolsey, T. S., Jr., *Western Yellow Pine in Arizona and New Mexico* (Forest Service Bulletin 101, 1910, pp. 48-51-52).

Overmature stands of this species are from 250 to 400 years in age. At 200 years average tree is about 21 inches in diameter and it is argued:

"All available figures indicate that it will take 200 years to grow saw timber. be seen . . . that diameter growth begins to fall off at from 100 to 160 years that height growth declines from the mean annual from 170 years. . . . this tainly the minimum size (21 inches) that can be estimated to yield timber of fair that will justify shipment. With thrifty, well thinned stands, however, it is hoped growth will be greater."

Obviously such a long rotation will be reduced with more intensive conditions even an author, such as Schlich, agrees that with extensive conditions and slow growth maximum rotations prevail. The rotation in question was preliminary in character merely facilitated the use of rough formulae methods of regulating the annual growth advisable at that time, crude though they may have been. Judging from Table 1 of the Bulletin,* on the basis of maximum mean annual growth a rotation of but 700 years might have been indicated, obviously impracticable, under the conditions enumerated.

As a contrast to the preliminary technical rotation of 200 years for the production of western yellow pine saw logs, the following specific rotation problem arose at the Pecos National Forest in Northern New Mexico and is instructive:

"The** rotation and cutting cycle will be adopted which will yield the product of the highest monetary stumpage value, involving a combined technical and financial rotation."

It was found that the greater the per cent of hewn ties in the final cut, the greater the stumpage value. Consequently, a rotation to produce this result was recommended and the problem was to find out from growth studies the size when western yellow pine (and other local species) produced the largest number of the most profitable ties. It was found that 14 and 15 inch trees were the optimum tie trees, because "less than 14 inches yield no square ties and no firsts." There was a wider margin of profit on the firsts than on the seconds. With this data as a basis the rotation established was the approximate number of years it takes to grow a western yellow pine tree 14 inches in diameter breast high—in this case 120 years. An average rotation was established on the basis of the dominant species, since it was considered impracticable to have separate rotation for different trees. The conclusion was also reached (as was to be expected) that "the shorter the rotation, the freer will be the forest from disease." (See also *Silvicultural Rotations*.)

The factor of the size and quality of boards in the determination of rotation must also be considered. For example, in the case of loblolly pine, 20 to 30 years would be a sufficient rotation, if round-edged box boards are desired; 35 to 40 years if part of the product must be a fair grade lumber; and 50 to 100 years if a considerable per cent of the lumber of the best grade is to be produced.***

Short technical rotations may be chosen for the production of cordwood, mine props, pulpwood, fence posts, telephone poles, box boards, and such classes of product which can be grown in less time than can large sawtimber.

43. Definition and Discussion of Silvicultural Rotations. *Silvicultural rotations are based on the limitations of the species to reproduce or to resist disease.* If a species produces seed prolifically between seventy and one hundred years of age, and regeneration must be by natural means, it would be logical to

* Woolsey, T. S., Jr., *Western Yellow Pine in Arizona and New Mexico* (Forest Service Bulletin 101, 1910, pp. 48-51-52). This rotation of 200 years has been confirmed by recent investigations.

**Korstian, C. F., *Hewn Tie Versus Saw Timber Rotations* ((P. S. A. F. Vol. 1916, p. 315).

*** Ashe, W. W., *Forest Management of Loblolly Pine*, 1914.

* Termed physical rotations by William Schlich in his *Manual of Forestry*, Vol. 1911, pp. 200-201.

mit the rotation to within those periods. In sprout forests a silvicultural rotation to the rotation chosen would be imposed by the limit of power to cut. In case the coppice failed to sprout after it reached an age of seventy years and the treatment had to be simple coppice, naturally the forest would rot, if a rotation of over seventy years were chosen. In this case silvicultural factors would be an absolute bar to a longer rotation. According to Endres*

some believe it to mean the rotation which would leave the stand with complete reproduction.** With high forest (that time) was when the seed production was best and when the soil was most receptive. With coppice it was within the sprouting of the stumps Others believed the rotation to mean the time when the stand is silviculturally mature or when the growth stopped."

is a matter of fact if the rotation is an economic or financial one this loss or of loss from rot will usually be eliminated because any intensive rotation (economic or financial) will fall before rot is a menace. The danger of rot, however, must be carefully considered when high quality saw timber is grown under a technical rotation or where the rotation is lengthened in protection forests.

There is also the limit placed by decay, but strictly silvicultural rotations of little real*** importance unless considered in connection with other series of rotations. Silvicultural requirements for reproduction or to avoid decay and other losses must perforce limit all rotations but rarely are the sole determining factor.

Illustrations of Silvicultural Rotation Limits. As Meineike* points out:

for a species such as white fir shows an increasing amount of defect after eighty years, a rotation should certainly not be chosen that would necessitate holding stands beyond that period; to do so would court unnecessary loss through decay."

This factor of rot will be found to set a limit to the feasible rotation for other species. In western yellow pine Long** found,

that during the blackjack period (up to 180 years) the trees are practically free from rot (western red-rot) "while trees over 200 years old show a much higher percentage of rot than the younger trees (blackjack) It is a fundamental fact that the older a tree is, the more liable it is to be attacked by heart-rotting fungi."

The following table by Zon*** furnishes another excellent illustration of a combined technical and silvicultural rotation:

Endres, p. 244.

Roth, Filibert, in his *Forest Regulation* terms this a *physical* rotation. He also defines a natural rotation which "is the natural life of the species, which hardly deserves separate nomenclature or description."

* Recknagel, A. B., in *The Theory and Practice of Working Plans*, 1913, New York, pp. 39-40, mentions also a latent rotation which hardly deserves the term rotation; he defines it as "just double the average age of the working figure" (working group).
* Meineike, E. P., "Forest Pathology and Forest Regulation" (Forest Service Bulletin 275, 1916).

Long, W. H., *A Preliminary Report on the Occurrence of Western Red-Rot in the Ponderosa* (Plant Industry Bulletin 490, 1917, pp. 7-8). The term pathological rotation seems superfluous.

* Zon, R., "Chestnut in Southern Maryland" (Forest Service Bulletin No. 53, 1904).

Kind of product	Trees from seed (age years)	Coppice (age years)
Post	27	14
Tie	41	29
Pole	49	38
Rail	54	43

According to Zon,

"Chestnut (sprout) is not suited to the production of large timber on account of unsoundness and short clear length when it has reached the desired size. There is even if large timber is desirable, chestnut should not stand longer than seventy-eight years, and coppice will then fill requirements better. Only in exceptional cases . . . should chestnut be left standing ninety years or more."

According to the above table, if the main product is chestnut ties, the rotation of trees grown from seed, must be at least forty years; but if coppice, only thirty years.

With sprout reproduction, as has been explained, the forester cannot delay cutting until the sprouts are no longer vigorous. Therefore, mean maximum ages cannot be established, beyond which it would be dangerous to hold sprout stands. For chestnut (prior to the chestnut blight) this maximum age was approximately 75 years; for chestnut oak, 45; for other oaks, 25 to 35 years. As to choice of material, whether cord wood, lumber, ties or poles, it is simply a local problem which must be worked out according to the conditions of haul and stumpage prices. According to the growth studies made by Frothingham,* the average annual growth culminated for chestnut on sites 1 and 2 at 35 years; on site 3, at 40 years; for chestnut oak on sites 3, at 40 years. The general conclusion was reached that for ordinary hard wood sprouts in Connecticut a rotation from 30 to 40 years was advisable, but that (prior to the chestnut blight) chestnut sprouts may be held up to 75 years if lumber is to be produced. This should be the correct application of this technical phase (in connection with other factors) before the decision is reached as to the rotation period.

45. Definition and Discussion of Economic or Quantitative Rotation

Economic (or quantitative) rotations attempt to secure the maximum average volume production per acre and are based on the culmination of the mean annual growth read from yield tables, and not on the maximum growth of individual trees.

The point in the yield table, where the mean annual growth** culminates, indicates the economic rotation. This point is readily determined after it has once been established what part of the tree is to be included as volume. Expressed as a simple formula it is as follows: $\text{Final yield} \div \text{intermediate yield} \div \text{number of years}$. In the United States when the board foot unit is used this culmination of mean annual growth will vary, (1) according to the log rule used, (2) depending on the utilization standards, especially regarding top cutting limits, and (3) according to the class of material which is included in the computations of volume. Because of these complications it is desirable when practicable to use other units, such as the cubic foot.

(1) *Effect of Log Rule.* With a log rule which gives large volumes for small sized trees, the tendency would be to shorten the rotation because with such a rule the mean annual growth would culminate earlier. With a rule

* Frothingham, E. H., Second Growth Hard Woods in Connecticut (Forest Service Bulletin, 1912, p. 45).

** See Forest Mensuration, H. H. Chapman, for the curves of current annual and mean annual growth.

put proportionately small values on small logs and too generous values on large logs, the culmination (other factors being equal) of mean annual growth would be retarded and consequently the rotation would be lengthened.

2) *Utilization Standards.* The smaller the top cutting limit, the shorter would be the indicated economic rotation because with a larger top cutting limit a longer time must elapse before an appreciable proportion of the tree is merchantable.

3) *Class of Product.* If small sized ties are the most desired product, it early follows from (2) that the economic rotation will always be shorter than if a larger class of product must be marketed. The culmination of the mean annual growth of small ties (even if expressed in the common factor of board feet) will be earlier than if the culmination in *board feet* is computed on the basis of saw logs. This is a phase which is also present in technical rotations.

According to Munger,*

It is the policy of the Federal Government to administer the public forest lands in a way as to perpetuate as forest all the land which is better suited to the production of timber than anything else, and to make it yield for all time the greatest quantity of the best quality of timber."

6. *Choice of Economic Rotation with Illustrations.* The most satisfactory basis for a choice of economic rotation is the total production of material according to a specified unit of product, such as board feet, for a specified volume of sawtimber, cubic feet (or cords) for pulp wood, linear feet of converter ties with a top limit specified, or cords of fuel. Where, as usually happens, the product from the ripe tree must be in three classes, such as board feet, ties and cordwood, the gauge of quantity must be expressed in a common unit which can serve as a basis for the comparison of the standard volume at different ages; otherwise three different quantitative rotations might be indicated, which is impracticable because three classes of product are derived from one and the same tree. In such a case often the most logical procedure is simply to adopt a financial rotation (see Chapter V) since then the common basis of comparison will be the dollar. Endres shows that the culmination of the mean annual growth is earliest on the richest soils and it is well to bear in mind that,

The rotations on the better sites are often shorter than financial rotations for managed high forests where the market conditions are bad."

According to European yield tables** the economic rotations are approximately as follows:

Timber quality	Pine (Schwappach)	Spruce (Baur)	Fir (Schuberg)	Beech (Schuberg)
	—Age in years when mean annual growth culminates—			
I	35	50	55	70-75
II	40-45	60-70	60-65*	80-85
III	50-60	70-80	70-75	85-95
IV	75-80	60-80	85-90	95-100
V	.....	.....	95-105	100-110

Munger, Thornton T., Western Yellow Pine in Oregon (Forest Service Bulletin, 1917, p. 36).

*Endres, p. 245.

The above figures, however, only serve to illustrate that the rotation which produces the largest amount of wood is not necessarily the best, except perhaps in localities in which coal is scarce and transportation very poor. As Endres puts it,

"In the present age of commercialism, it is no longer a case of the greatest volume but of the highest money return for the best product that is the controlling factor in fixing the rotation."

Whether this will apply to American conditions is a question. If there is a national timber shortage, it would be easy to justify rotations that would produce the greatest quantity of product required by the nation.

Illustrations of economic rotations. The Forest Service (District I) determined:

"The maximum yield for (western) white pine under average conditions occurs at 120 years and the rotation has been fixed accordingly. In the case of lodgepole pine, however, another consideration enters into the problem. It has been determined that at the age of growth culmination the trees are too small to supply the local demand. Hence, a longer rotation than indicated upon a straight yield basis has been established."

This determination of the rotation of lodgepole pine is of interest because the rotation could not be established solely on the basis of maximum mean annual growth since at that time sufficient merchantable material would not be produced. The objects of management in this case were not only watershed protection but also a maximum sustained yield for merchantable timber of the *most desirable sizes*. According to Mason:

"The length of the rotation . . . is determined by the rate of growth . . . for the purpose for which the wood is to be used. Because of the slow growth of lodgepole pine and the necessity of raising large sized ties, a longer rotation must be chosen than would be indicated by the culmination of mean annual growth at 70 to 90 years on different soil qualities. A rotation of this length, however, gives few trees 9 inches or more in diameter and is, therefore, too short."

If the material was cut to 6 inches in the top, the board foot mean annual growth culminated at 130 years, while if cut to 8 inches in the top, the culmination is delayed to from 200 to 210 years. At 130 years only $\frac{3}{5}$ of the material produced is 8 inches or more in diameter at the top end, while at 200 years nearly $\frac{9}{10}$ of the material produced is merchantable. The author therefore concludes that,

"The mean annual growth in board feet to a 6 inch top is nearly at its maximum at 140 years, when 53 per cent of the scale material is 8 inches or more in top diameter. . . . Such a rotation is the best for normally stocked lodgepole stands on average sites in Montana."

This is a sound method of analysis, but with thinnings the limitation as to size will probably be largely done away with because there would be fewer trees but with a larger size in the top. There is no objection to basing the economic rotation on the culmination of mean annual growth taking into account *only trees of the most desirable size*.

In a quality I second growth white pine** stand, at 55 years of age the mean annual growth is 1000 board feet; at 60 years it has risen to 1003 board feet and at 65 years to 1002. In this case the quantitative rotation for first quality soil would be sixty years if based on the board foot yield. For the same quality of soil in this table, but in cubic feet, it will be noted that the culmination is at fifty-five years. A still different culmination of mean annual growth would have occurred if the board feet had been computed by a different log rule or with different cutting limits in the type or different standards of utilization. It is therefore evident that in determining a quantitative r

* Mason, D. T., Utilization and Management of Lodgepole Pine in the Rocky Mountains (Forest Service Bulletin 234, 1915, 22-3. Special reference is made to table p. 22).

** Reference is made to table 7, page 24, in White Pine Under Forest Management by E. H. Frothingham (Forest Service Bulletin 13, 1914).

It is necessary to give the exact data upon which it is based. Quantitative rotations never based upon current growth.

According to the Forest Service (District 6),

in the Douglas fir region we are now operating on a tentative rotation of 100 years. Overstock, however, is so large that we are not very vitally concerned at present with the length of rotation In the yellow pine region we have assumed a rotation of 180 years with a cutting cycle of 60 Until we have more specific data as to the rate of growth after cuttings (making allowance for increased growth, natural loss, etc.) and know more about the silviculturally most desirable method of logging, I don't see how we can arrive at the ideal rotation and cutting cycle."

Wiley's* conclusions (basis not given but probably economic) as to the proper rotations for intensive forestry around New Haven were as follows:

Hardwood type	60-80 years
Hemlock type	80-100 years
Pine type	50 years

These conclusions are obviously tentative.

According to Chapman's investigations** Ashley County, Arkansas, the shortleaf pine on an economic rotation should be grown in 100 to 110 years; probably in the majority of cases the rotation indicated by this local study will be less rather than more. Mention was made by*** Graves of rotation, but after showing that trees were profitable for pulp down to five or six inches inside bark on the stump, he analysed the diameter limit of cutting. He showed that if spruce trees were cut to six inches there would be 75 years between cuts of equal size; if to 8 inches, 50 years; while if to 10, 12 or a 14 inch limit, there would be a correspondingly shorter interval between equal cuts. He selected 10 inches in this case as the diameter limit because

the owners wished to obtain the greatest possible immediate return without seriously impairing the productive capacity of the forest and are willing to wait for a longer period for a second cut."

A diameter limit corresponds roughly to a rotation of 165 years. This has the character of an economic rotation, but the fallacy and danger of using any diameter limit in irregular stands must be recognized.

The Norway pine mean annual growth culminated at 130 years, curiously enough on the later the* culmination of mean annual growth and hence the longer the economic rotation.

According to Mattoon,** rotations depend largely on (1) The age when the mean annual growth is greatest, (2) The kind of material desired, and (3) The total cost of producing the material.

Each conception involves an economic rotation, a technical rotation and a financial rotation, but this same writer concluded that the most reliable basis is the time when mean annual production is greatest (i.e., economic rotation). For short leaf pine Mattoon concluded that the economic rotation for site II stands in North Carolina

Jawley, Ralph C., A Working Plan for the Woodlands of the New Haven Water Company (Yale Forest School Bulletin 3, 1913, p. 25).

Chapman, H. H., Prolonging the Cut of Southern Pine (Yale School of Forestry, Bulletin 2, 1913, p. 8).

* Graves, H. S., Practical Forestry in the Adirondacks (Bureau of Forestry, Bulletin 1899, p. 64).

Woolsey, T. S., Jr., and Chapman, H. H., Norway Pine in the Lake States (Forest Service Bulletin 139, 1914, p. 26).

Mattoon, W. R., Short Leaf Pine, Its Economical Importance, and Forest Management (Forest Service Bulletin 308, 1915, p. 32).

was 90 years; for sites in Arkansas, 100 years, but for New Jersey, 45 to 50. This is for sawtimber. If the mean annual growth culmination is based on total volume without consideration of size, then the culmination comes 20 to 30 years earlier when sawtimber must be produced; on site I, at 50 to 60 years, on site II, at 60 years, on site III, at 85 years. These rotations would be decreased by 15 to 30 years with early and frequent thinnings. The specific rotation recommended for conifers on the Arkansas National Forest, where the aim was "to produce the sort of material most needed by the people, which is mostly medium sized sawtimber," is 90 years, which will produce an average tree of 15.9 diameter containing 240 board feet.

47. Quiz. What is a rotation?

Explain cutting cycle.

What affects the length of rotation?

Should the rotation be based on present statistics or on possible future changes?

Discuss intensive and extensive rotations.

Define technical, silvicultural, economic rotations.

What kinds of financial rotations are there? (see chapter V).

How do economic rotations differ from those based on the forest rent theory?

Illustrate when technical rotations are advisable.

Is this kind of rotation best suited to public or private management?

Why do technical rotations sometimes entail financial losses?

Is it safe to base the decision as to the length of rotation purely on technical growth?

Illustrate a silvicultural rotation?

Is this a safe basis upon which to base a rotation?

How are economic rotations established.

How is it affected by log rule, utilization or class of material harvested?

Would an economic rotation for pulpwood closely agree with the best financial rotation (forest rent)? financial rotation (soil rent)? (see chapter V).

Discuss and comment upon the economic rotations for various species and show how these will be modified in the future.

CHAPTER V

FINANCIAL ROTATIONS

Definition of Financial Rotations and Related Subjects. Before defining financial rotations let us repeat the definition for forest rent and soil

Forest rent is the net income from a forest organized for sustained yield without interest charges on the forest capital,—bookkeeper's balance,—the forest, i.e., with a stand or growing stock, being conceived as the forest capital, and the interest as the total interest earned thereon. (G., Waldrente.)

Soil rent is that part of the income (or balance) from a managed forest which remains as interest on the soil capital alone after all expenses with compound interest have been deducted, the soil alone being conceived as the capital. (G., Bodenrente.)

Our definition then is:

Financial rotations aim at securing the highest monetary return. This rotation varies depending on whether the return is figured on the basis of forest rent or soil rent.

*Financial rotations introduce considerations of cost and attempt at securing either the maximum forest rent or maximum soil rent. The maximum forest rent rotation is that which yields the highest net mean annual net money return without compound interest; the maximum soil rent rotation is that which yields the highest return (at compound interest) per dollar invested.**

Before discussing financial rotations let us bear in mind the definitions for capital value in their various phases (As explained in the preface, the terms and definitions are in the form adopted by the S. of A. F., see J. of F., Vol. XV, 1917, pp. 68-101):

One factor of production in the forestry business is variously figured according to the parts of the investment are referred to and what basis of valuation is applied.

Fixed capital refers to such kinds of capital as are not used up in production, like land and soil.

Working or operating capital refers to money capital needed to supply current expenses in operating a forest.

Soil capital refers to the value of the soil figured in various ways.

Stock capital refers to the value represented by the wood material of all stands comprising a forest or working circle.

Forest capital refers to soil capital and stock capital combined.

These capitals may be used following the precedent of Pressler in his index per centum for the combined soil and working capital.

These capitals may be based upon various kinds of values, and to secure a definite meaning, the term must be qualified by the method by which its value was determined. The following values may be differentiated:

Investment value—the purchase price or the actual expenditures or investments that have been made in acquiring or creating the property with interest, less incomes actually received from it, with interest. (G., kostenwert).

Market or exchange value—the market price based on statistics of actual sales: a special kind of sale value is the forced sale or wrecking value that can be obtained by exploitation of saleable parts (see stumpage value) (G., verkaufswert; F., valeur venale).

49. (A) Rotations for Maximum Forest Rent or Highest Mean Annual Net Money Return. This form of rotation is exactly similar to the economic (or quantitative) rotation except that the yield unit is expressed in money with the costs of operation deducted—a common standard of comparison. The cost of establishing the stand is deducted so that the net mean annual per acre income can be figured for each decade. The decade with the largest mean annual return is the forest rent rotation indicated. This is a more intensive form of rotation than the economic (or quantitative) already described but less intensive than a financial rotation based on the soil theory described later, where the costs are figured at a definite rate of compound interest and all costs and returns discounted to a definite date so as to have a uniform basis for comparison.

The forest rent formula is as follows:

$$\frac{(\text{Final and intermediate returns}) - (\text{expenditures}),}{\text{number of years}} \quad \text{or using the terms like}$$

$$\frac{(\text{F\$} + \text{I\$}) - (\text{C\$} + \text{A\$})}{N}$$

50. Illustrations of Maximum Forest Rent. As yet there are few examples in American forestry of rotations for the highest mean annual net money return. The following table is from Endres*:

TABLE 2. Synopsis of gross returns, expenditures, and mean annual net return in dollars per acre for a fully stocked quality III spruce stand.

Rotation years	Gross Returns			Expenditures			Net Returns	Current annual returns	Mean annual return
	Final	Intermediate	Total	Planting	Administration	Total			
30	\$ 48.30	\$ —.—	\$ 48.30	\$8.00	\$18.00	\$26.00	\$ 22.30	\$ 5.89	\$ 5.89
40	109.10	4.10	113.20	8.00	24.00	32.00	81.20	8.12	8.12
50	188.00	12.40	203.40	8.00	30.00	38.00	162.40	7.78	7.78
60	259.00	25.20	284.20	8.00	36.00	44.00	240.20	9.31	9.31
70	345.30	38.00	383.30	8.00	42.00	50.00	333.30	11.27	11.27
80	451.00	51.00	502.00	8.00	48.00	56.00	446.00	11.08	11.08
90	554.20	64.60	618.80	8.00	54.00	62.00	556.80	11.92	11.92
100	666.20	77.80	744.00	8.00	60.00	68.00	676.00	9.82	9.82
110	759.40	88.80	848.20	8.00	66.00	74.00	774.20	6.58	6.58
120	821.80	98.20	920.00	8.00	72.00	80.00	840.00		

In the preceding table the maximum forest rent (*mean annual*) falls at 110 years and it amounts to \$7.04 per acre per year. The maximum *current* income comes between 100 and 110 years.

Stock or stumpage value—based on sale value of material ready for immediate utilization (Synonym, utilization value) (G., *nutzungswert*).

Expectancy value—the present worth of all estimated or expected future net earnings (discounted to the present); the capitalized net income value (G., *erwartungswert*, F., *valeur d'attente*).

Rent or yield value—a value, determined by capitalizing, with a demanded rate of interest, the yearly or intermittent net return possible to be derived from a managed property. (See forest rent and soil rent) (G., *bodenrentierungswert*, *waldrentierungswert*).

* This table was taken from Endres, *Lehrbuch der Waldwertrechnung und Forststatistik*, page 233. Marks per hectare were reduced to dollars per acre by dividing by 10. The yield was calculated for spruce, quality 3. This table has been used in slightly different form by other American writers.

Endres* gives another method of figuring what he terms "value increase per cent" which is virtually growth per cent expressed in money with expenditures deducted. The calculations are as follows:

$$\text{Value per cent at 110 years} = \frac{100}{110} \left(1 + \frac{\$88.80 - \$8.00}{\$759.40} \right) = 1.006\%$$

$$\text{Value per cent at 100 years} = \frac{100}{100} \left(1 + \frac{\$77.80 - \$8.00}{\$666.20} \right) = 1.105\%$$

The stand is therefore not ready for cutting because 1.105 is greater than 1.006," as by the above mentioned author.

$$\text{Value per cent at 120 years} = \frac{100}{120} \left(1 + \frac{\$98.20 - \$8.00}{\$821.80} \right) = .925\%. \text{ Here,}$$

the stand has passed the cutting period because .925 is less than 1.006."

This formula may be expressed as follows:

$$\text{Value per cent} = \frac{100}{\text{rotation}} \left(1 + \frac{\text{Intermediate yields} - \text{planting costs}}{\text{final yield}} \right)$$

This is a formula of technical interest but its use would not be necessary because the rotation is more readily determined by a direct computation of the net mean annual income for different rotations. Where true per cents are calculated, other factors must be taken into consideration.

3. Distinction Between Forest Rent and Soil Rent with Illustrations.

The distinction between forest rent and soil rent rests on the difference between income per acre without interest and income per dollar invested with compound interest. This difference is thus discussed by Endres:

The manner in which interest accumulates is shown in the following table, figured on each high forest (with interest at only 2%):

Rotations	30	40	50	60	70	80	90	100	110	120 years
Forest rent	\$0.74	2.03	3.25	4.00	4.76	5.58	6.19	6.76	7.04	7.00
Soil rent	\$0.23	1.00	1.56	1.75	1.89	1.98	1.95	1.88	1.71	1.47
Interest on capital	\$0.51	1.03	1.69	2.25	2.88	3.60	4.24	4.88	5.33	5.53

In a beech high forest the largest mean annual forest rent per acre gave a total of \$7.04 at a rotation of 110 years. When 2% interest is used then the total of the soil (value) in the same year is \$85.50, making the annual soil rent $\$85.50 \times 0.02 = \1.71 . The difference equals,

110 years) {	soil rent	\$1.71
	interest on the accumulated wood capital	5.33
	Total	\$7.04

The largest soil rent value is figured for a 80-year rotation with \$98.80. The mean annual forest rent for the same rotation carries annually \$5.58 per acre. This gives,

80 years) {	$\$98.80 \times 0.02$	\$1.98
	interest on the accumulated wood capital	\$3.60
	Total	\$5.58

The true "rent" which is possible through the managing of the forest income, lies in soil rent which is determined by adhering to the rotation of the highest forest rent. The difference between soil rent and forest rent, i. e. the interest on the accumulated wood capital, is nothing more than an expenditure which is necessary to make in producing the soil rent. The forester must subtract this from the forest earnings, or, commercially speaking, to equalize the expenses incurred on accumulating debts.

In our example the forester has a yearly income of \$7.04 per acre by adhering to a 110-year rotation. If he figures correctly, he will subtract \$5.33 as costs of the enterprise and he will actually net only \$1.71 (soil rent). By adhering to the financial rotation he earns an average of \$5.58 per acre. The expenses demand only \$3.60; so he nets \$1.98.

Endres, p. 234. Since no comprehensive original work has been done in the U. S. on soil rent calculations, it was thought best to give a translation of the best German literature on the subject.

"The greater profit which the 110-year rotation has over the 80-year rotation is an *ostensible one*. In reality the 80-year rotation brings the forester a greater net" (\$1.98 — \$1.71 = \$.27) per acre over the 110-year rotation.

"The yearly loss, which the forester suffers through the shorter rotation . . . equal to the gain between soil rent and forest rent.

"In consequence of the previous facts, it is evident that the *highest income in connection with area is made in managing for forest rent*.

"This is true when we consider forest rent as a clear profit. In reality this is no case. The greatest part of the forest rent is made up of interest on stored-up capital that becomes larger, the longer the timber remains in the woods, i.e., the longer the rotation. This interest, as mentioned before, is no gain to the forester but enterprise expense or debt that has to be met out of the forest rent.

"In 'Handbook of State Investigations,' III Vol., p. 602, the following explanation is given of managing for forest rent: 'The followers of this idea figure the forest rent box out of which we can take, periodically, a sum of money called rent. How this will require for expenses causes no worry.' The remarks by Bose, Ulrich and against this, given in 'Centralblatt,' 1893, are of scientific interest.

"The forest rent thus comes at 110 and the highest soil rent at 80.

"We can also say that by changing the rotations which brought the highest forest rent we change conditions (that existed since the primeval world) since the forest has always been handled under this rotation. The forest owner, whether private or public, will necessarily suffer a clear loss. This is also true in a spruce forest with a working group of 110 acres; using a 110-year rotation will give a forest rent of $7.038 \times 110 = \$774.20$; using a rotation of 80 years gives a yearly forest rent of $5.58 \times 110 = \$613.25$. The net gain in yearly forest rent amounts to $\$774.20 - \$613.25 = \$160.95$. This, however (if we consider soil rent) will be more than used up by the interest earned on the stored capital, that had been liberated due to an earlier rotation. This capital is $\$5.33$ capital at interest per acre for the 110-year rotation, as follows:

$$\frac{\$5.33}{\$0.02} \times 110 = \$29,315;$$

and for the 80-year rotation,

$$\frac{\$3.60}{\$0.02} \times 110 = \$19,794.50,$$

the excess ($\$29,305 - \$19,794.50$) being $\$9,510.50$. The owner has this $\$9,510.50$ as savings (gold coin) drawn out of the forest and can put it in the bank at interest. Should he get only 2% interest, he earns a yearly rent of,

$$\$9,510.50 \times 0.02 = \$190.21,$$

which amount easily makes up the forest rent gain. The actual yearly income gained through shortening the rotation is shown as follows:

$$\begin{array}{r} \text{80-year rotation, } \$613.25 + \$190.21 = \$803.46 \\ \text{110-year rotation, } \qquad \qquad \qquad \$774.46 \end{array}$$

$$\text{Clear gain from 80-year rotation} \qquad \qquad \qquad \$29.26$$

Should the forester receive a 3% interest rate on the liberated capital (this rate being quite possible), it will give an interest gain of,

$$\$9,510.50 \times 0.03 = \$285.31$$

and thus the clear yearly gain will be,

$$(\$613.25 + \$285.31) - \$774.20 = \$124.36.$$

Now from the practical side a rotation cannot be changed so quickly in spite of pecuniary gain on the liberated capital. Besides overstocking the local market, which may be of some importance, we also upset the normal handling and normal condition of the stand. It is necessary (for such an undertaking) to formulate a definite working basis and allow time for the complete use of the liberated stock (timber). A primary consideration is the proper investment of the drawn out capital. If there is danger of not properly disposing of the capital, then it had better remain in the forest in spite of the fact that it earns no interest

The fundamental principles of the Forest Rent Management as compared to the Forest Management are:

"(a) The forest rent theory is determined by the rotation as based on the future earnings. The fundamental difference between the methods of rotation lies in the fact that in soil rent management discounts the intermediate earnings and costs to a definite period with compound interest, while the forest rent management simply adds and subtracts without considering compound interest

"(b) The forest rent management is built up on future earnings and costs. If we want to determine the time the forest rent culminates in a 30-year-old stand, we have to consider the earnings and the costs that are expected to take place at 80 years, therewith figuring the rotation of the greatest forest rent.

"Therefore the belief that the forest rent theory fixes with more* certainty the rotation

* When the forest becomes a "going concern" the opponents of the soil rent theory

period than does the financial (soil rent) rotation is fallacious and the adherers to belief are misled.

The rise and fall in earnings and expenses due to price changes has a profound influence on the rotation period.

An increase in operating costs and rise in stumpage value lengthens the forest rotation and vice versa. *An increase of thinnings shortens rotations*, whereas a lessening of thinnings lengthens them. (Read, Loreh's, Handbuch der Forstwissenschaft, II,

it is noticeable that a change in price level has more influence here than in the soil rent theory A very small price increase (\$.31) lengthened the rotation from 120 years.

The flexibility of the rotation period with change in price level carries with it strict adherence to the principle that any excess or defective growth should be used off.

From this viewpoint the rotation of greatest forest rent has no advantage over the soil rent rotation. The advocates of the forest rent theory put it as a matter of fact in the state forest operations the shortening of the rotations is done on the principle of highest forest rent. This assumption is ill founded. In actual practice the rotation of the highest forest rent is much higher than is usually accepted.

It is pointed out that Weber argues correctly when he shows that practical conditions must have weight in the choice of the rotation. Besides one must take into account, the growth of the final stands, the yield from periodic thinnings, average price per cubic meter, relative profit from different species, intermediate costs, cost of administration and supervision, and state and municipal taxes."

Kirkland* argues that if all age classes are present in a forest, it is not necessary to compound interest in determining profit because,

since we are determining the current annual results year by year, compound interest is not involved. In other words we are working on a forest rent basis; i.e., what will the forest earn each year on the investment? Particular emphasis should be laid on the fact that today we have large forests, and that any effective forestry work we do must be done with these forests. Therefore, we can best work on the forest rent basis. Any error we do on bare tracts will be insignificant."

This viewpoint does not agree with the best European mathematical theory as has been seen by Endres's discussion of the relationship between forest rent and soil rent. With the present widespread forest destruction in the United States it would appear that we must deal with bare soil. For a more complete discussion of the subject see books on valuation. It should be emphasized however, that in the United States soil rent rotations will usually be rejected for silvicultural and policy reasons and not because soil rent is not mathematics.

The idea that financial rotations can be based on the growth per cent of the trees has not gained credence in America. Few would agree that the yellow poplar** "can be considered mature financially when their annual rate of increase in value becomes equal to the correct rate of interest on money." No definite number of years is mentioned as the rotation, but instead maximum rotations according to different costs of operation and different sites.

(B) Rotations for Maximum Soil Rent or Highest Returns Per Acre Invested. Here the criterion of profit is the maximum revenue with expenses deducted, but all statistics must be carried at compound interest at an estimated rate. The customary method of computation is to figure the expectation values for different ages; the largest expectation value

is the more plausible arguments, but as a matter of fact if the forest devastation continues in the United States there will be few forests that are "going concerns."

Kirkland, Burt P., Continuous Forest Production of Privately Owned Timberlands: A Solution of the Economic Difficulties of the Lumber Industry. (Journal of Forestry, Vol. XV, 1917, pp. 41-42.)

Ashe, W. W., Yellow Poplar in Tennessee, 1913, p. 36.

denotes the most profitable rotation or the rotation of maximum soil value. The following is a complete formula for expectancy or soil value:

$$\text{Expectancy or Soil Value (see table of symbols)} = \frac{F\$ - C\$}{i \cdot op^n - 1} - (C\$ + A)$$

For further details see § 116, page 92 of *Forest Valuation* by H. H. Chapman.

According to Schlich,*

"The expectancy value indicates the true economic value of the soil for forest culture because it is based upon the productive power of the land used for the rearing of forest crops."

For practical purposes, if only the rotation is to be determined (and the actual soil value), the following formula is sufficiently accurate:

$$\text{Expectancy value} = \frac{\text{final yield} + \text{intermediate yields}}{i \cdot op^n - 1}$$

The reason why this formula is a judicious approximation is that an expense has no real influence on expectancy value, the cost of formation of soil value almost none, and the yield from thinnings very little. There are two very important factors, namely, (a) rate of interest and (b) final yield.

53. (a) What Rate of Interest Should Be Used? The rate of interest is the most important problem and has been made more confusing by world inflation incident to the Great War. Low interest rates mean low financial rotations than do high rates. Schlich** shows that (for a Scotch pine forest) if the interest rate was $2\frac{1}{2}\%$ (the rate often chosen for calculations in England), there would be an indicated rotation of 80 years. Increasing this rate to 3% and the rotation (based on the expectancy value) would be 70, and if 4% , only 60 years.

Most European authors agree in the theory that a forest which yields permanently the highest net annual income (with interest) is the greatest benefit to mankind, other things being equal. On the other hand, there is a tendency on the part of the individual (and still more so if the state owner) to forget past interest expense, if by holding a stand to a longer rotation, the gross or apparent net yield per acre is increased. Only when past expenditures constitute an obligation which must be met, and hence earned, will the true financial relation between cost and income (with interest compounded) be the determining factor in the rotation.

As a matter of fact no one would argue that the state should take financial profit as its sole object in forest management, but it is usually admitted that the public welfare may be best served by giving proper consideration to wood production along with a regard for the obligation to raise the largest amount of product most keenly needed by the locality. The public forests belong to the whole nation and the object of a financial rotation should be the highest possible production of material both for present and future generations. One of the main drawbacks to a narrow conception of the necessity of following blindly a short soil rent rotation (untempered by sound silviculture) is that future production might be impaired.

* Schlich, Vol. III, pp. 127-129.

** Vol. III, pp. 127-29.

According to Roth,*

- 1) The "normal" forest of central Europe in ordinary rotations yields 2 to three per cent on the sale value of the forest.
- 2) This per cent is independent of site.
- 3) Beech and oak exceed pine and spruce (in rate of interest) on one hundred and twenty-year rotations, because the growing stock is a less important part of the capital.
- 4) The rate varies in narrow limits for all reasonable rotations and is little affected by current expenses.
- 5) The rate does not materially vary with changes in stumpage value because capital and income are affected in like manner.
- 6) Extensive forestry with small expenses and small incomes yields practically as good a per cent as intensive forestry.
- 7) It is very doubtful if any business rate over four per cent should be paid in forest investments (pre-war conditions).

According to the figures cited by Roth, the per cent yielded by pine, spruce, fir, and beech, under ordinary rotations on four different sites of soil, is shown in the following table:

TABLE 3. Rate of Interest Earned in European Forestry.

Site Class	Pine	Spruce	Oak	Beech	Oak—160-year rotation
I	2.2	2.5	3.6	2.9	2.2
II	2.1	2.6	3.	2.9	2.1
III	2.	2.6	3.3	3.1	2.1
IV	2.	2.7	..	3.	..

It is clear that the quality of the soil does not materially affect the rate of interest earned. The inference that may be drawn from these figures is that the rate used for compound interest calculations should be from 2 to 3%, but there must be periods, such as during 1914 to say 1930, when such rates appear low. But most calculations lead to false conclusions if high rates of interest are employed; any rate over 3½% is doubtful. The length of the rotation is the crucial point.

54. (b) What is Influence of Final Yield? The final yield is next in importance. Quality increment of course increases the value of the final yield and hence lengthens the financial rotation.

Because of the lack of yield data and reliable stock figures and statistics on which to base calculations, the tendency (in American Forest Regulation) has of necessity been to ignore the need for computing financial rotations. For this reason a synopsis of what Endres says on the subject of financial rotations is given (in fine print, appendix A (b)).

* Roth, F., "Business Rate of Interest and Rate Made by the Forest." (Forestry Quarterly, Vol. 14, 1916, page 258.)

55. Illustrations of American Attempts at Calculating Maximum Soil Rent Rotations. One of the earliest intelligent discussions of rotation (with a financial viewpoint) found in American forest literature is by Allen in the western hemlock.*

In reply to the question, "At what age can the second growth stand be most profitably logged and how can the forest be perpetuated?" he showed that small size material "may be cut in 40 years and that in 50 years logs will be produced which would be considered a fair size in the East today." Analyzing the mean annual growth, Allen states that at 50 years 40 board feet per acre per year could be produced; at 60 years, 471 board feet; at 70 years, 471; and at 80 years, 500; i.e., the *economic rotation* already discussed. His conclusion was that "it appears, therefore, that the greatest production of wood can be secured by cutting second growth hemlock when it is about 80 years old." He admitted that other points should weigh in forming a correct conclusion, such as natural regeneration, quality of material and net financial profit. He stated that "rotation of greatest financial profit still remains to be reckoned . . . the calculation can only be tentative," but he concludes that 70 years is the most profitable financial rotation and that with \$1.00 stumpage per thousand feet, the investment would yield 4½% compound interest yet we must be cautious of advising too short rotations, building timber is what the world needs.

In an early state** report the conclusion was reached that,

"Whenever this interest (in the financial yield table) falls below the rate which may be earned by the money into which the timber can be converted, the forest should be cut."

The authors conclude that the lower the rate used in the calculation of compound interest, the longer the timber may be left standing. With 4% interest and no quality increase, the time to cut any stand would be hastened ten years. This table, however, simply indicates the maximum age at which cutting should take place and does not determine the exact time to cut, because to answer the second question, "must know the items entering into the cost of production. With compound interest at 4% it was found that for white pine in New Hampshire the net profit would be the greatest between 50 and 60 years of age—with land valued at \$5.00, cost of planting \$7.00, protection at 10 cents per acre per year, and current local tax rates on the timber and on the land. In addition to paying 4% on the money with a rotation of 55 years there would be a surplus of \$71.26, or an additional profit of \$1.29 per acre per year.

Frothingham's conclusions in regard to white pine rotations agree in the main with those (of the New Hampshire report) cited above, and he also agrees that the lower the interest rate, the later the financial maturity will occur. With 4% interest the owner can afford to hold the stand until it is 50 years old. If 6% interest is charged the rotation must be reduced to from 40 to 50 years or a loss will ensue. He is correct in concluding that financial maturity does not coincide with volume maturity, because the mean annual growth in board feet culminated on site (I), at 60 years of age; on site (II), at 75 years; on site (III), at 90 years. As Frothingham points out, seed years occur every 3 to 7 years, and if the stand is to be reproduced by natural means, it must be cut during a seed year. Therefore, it could rarely be cut precisely when financially mature***; this only serves to illustrate that rotation should be gauged by decades rather than by individual years, and that the final decision must be based on a number of considerations.

*Allen, E. T., Western Hemlock (Bureau of Forestry Bulletin 1902, pp. 44-48).

** Forestry Commission of New Hampshire, 1905-06, p. 240. Reference is made to table 21.

*** Frothingham, E. H., White Pine under Forest Management (Forest Service Bulletin 13, 1914, p. 36, special reference being made to tables 12 to 17, which deserve careful study).

Ashe* defines rotation as "the most profitable age and size at which to cut," and analyzes the rotation for loblolly pine in North Carolina, according to whether the stand is in mixed or pure even-aged stands. In these mixed stands the "most profitable age to cut can be determined by the rate with (at) which they increase in value." On the basis of these single trees the author argues that "when the rate of increase in value declines to 6%, the tree can be considered financially mature." In other words, the argument was based not on an investment per acre, but on the current income value of the tree, his conclusion being:

"Trees should be cut, therefore, when they are between 14 and 15 inches in diameter, at which size their rate of increase in value (neglecting increase in price) becomes equal to the current interest rate."

With pure even-aged stands grown for sawtimber, the most important consideration, according to Ashe, is the "largest average per cent of (net) profit," taking into consideration soil value, interest, taxes and administration, or in other words, the cost of production. The author admits that the expense of growing timber is variable, but in the calculations made, assumes a soil value of \$5.00 an acre and 6% interest. The decrease in soil value and stumpage value, he says, "will in part cover the cost of protection and taxes," but to be on the safe side, 1% should be deducted from the profit over taxes, protection and administration for the growing period, and he further contends that,

"Since there is no cost of stocking other than protection and leaving seed trees, the initial investment is practically limited to the soil value. The growth of the seed trees, if they are carefully selected, should approximately cover the interest on the initial investment."

This is illustrated in the following table:

TABLE 4. Value of Fully Stocked Stands of Loblolly Pine, as Scaled by Doyle-Scribner Rule, at Different Ages on Different Quality Sites and Under Different Costs of Operation; and the Per Cent of Interest on an Initial Investment of \$5 an Acre Represented by This Value.

Quality I					
Age of stand in years	Operating expenses \$11	Rate of compound interest on an investment of \$5 an acre	Operating expenses \$13	Rate of compound interest on an investment of \$5 an acre	Operating expenses \$15
		Per cent		Per cent	
25	\$ 33	8	\$ 18	6.1	\$ 4
30	74	9	42	7.0	10
40	143	8	87	8.0	30
50	231	7	158	7.0	84
60	326	7	243	6.5	159
70	423	..	336	6.1	249
80	496	..	406	...	316
Quality II					
Age of stand in years	Operating expenses \$ 6	Rate of compound interest on an investment of \$5 an acre	Operating expenses \$ 3	Rate of compound interest on an investment of \$5 an acre	Operating expenses \$ 1
25	\$ 6	0.8	\$ 3	...	\$ 1
30	31	6.0	17	5.0	3
40	80	7.0	47	6.0	14
50	132	6.5	84	6.0	37
60	193	6.3	136	5.5	80
70	267	...	206	...	145
80	325	...	261	...	196

Ashe, W. W., Loblolly or North Carolina Pine (North Carolina Geological Survey, Bulletin 24, 1915, pp. 135-137). It must be admitted that timber production will rarely be as high as 6% unless there are considerable stumpage increases.

Quality III

25	...	...	...	...	...	...
30	...	...	...	...	...	...
40	\$ 27	4.0	\$ 15	...	\$ 3	...
50	61	5.0	36	4.0	11	...
60	97	4.5	65	4.5	32	3.3
70	141	...	103	4.5	65	4.0
80	177	...	137	4.0	97	4.0

Different results would have been secured had the yield been based on mill. The conclusion was reached that the less favorable the quality site the later is the at which the maximum interest rate is attained; this agrees with the conclusion of European foresters. For pure even-aged stands of cordwood there is little, if any, increase in price with increase in size. Therefore, the volume of the stand and the rate of production are the proper bases for the rotation.

"The cheapest cost on all quality sites is when the stand is between 25 and 30 years old." Such short rotations are often veritable nonsense.

The conclusions on the cost of growing cordwood are illustrated by the following table:

TABLE 5. Cost of Growing Cordwood in Fully Stocked Stands of Loblolly Pine of Different Ages on Different Quality Sites on Land Valued at \$5 an Acre and Interest at Six Per Cent.

Stem Wood Only from Trees Six Inches and Over in Diameter.

Age of stand Years	Value of \$5 compounded at 6% for the period, less the initial investment	Cost of growing a cord of 160 cubic feet, peeled			Cost of growing a standard cord of 128 cubic feet, bark included		
		Quality			Quality		
		I	II	III	I	II	III
25	\$16.45	\$0.50	\$0.74	\$1.37	\$0.26	\$0.41	\$0.77
30	23.65	.55	.79	1.31	.31	.44	.77
40	56.40	.97	1.34	2.02	.59	.78	1.13
50	87.10	...	...	2.49	.83	1.05	1.43

According to Sterrett's investigations* on the ash,

"The financial rotation is lengthened by low yields, low stumpage values, and high initial investments, while the opposite of these shorten it."

It was argued that financial rotations may be altered according to the purposes for which the timber is grown; according to market conditions and seed year occurrence. From the silvicultural viewpoint short rotations are best, and long rotations in pure stands should be practiced only on the best sites, and then the ash should be usually underplanted. Rotations of 30 to 60 years are recommended.

Special reference is made to table 6, which follows:

* Sterrett, W. F., The Ash's, Their Characteristics and Management. (Forest Service Bulletin 299, 1915, pp. 35-39.) The costs of the crop $V_0 \times 1.06^n$ = value of the crop in years (Vn). When the costs of the crop is less as in poorer quality sites n must be greater where p is constant. See Chapman's Valuation. It should be noted that interest rates in forestry calculations are rarely possible or advisable.

Interest rates¹ (compound) to be expected on money invested in growing, where yield quality I, II, or III stands are secured, calculated for different npage values and for different initial investments.

(Blank spaces indicate less than 3 per cent interest.)

Board feet.

board feet.

Total initial investment per acre.																	
\$5. ²			\$10. ³			\$15. ⁴			\$20. ⁵			\$25. ⁶			\$30. ⁷		
Compound interest rates (per cent) for yield quality I, II, and III stands.																	
I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
4.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7.5	..	..	3.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9.6	..	..	5.9	..	..	4.3	..	..	..	..	..	..	..	..	..	..	..
I 11.1	..	..	7.3	..	..	5.6	..	..	4.1	..	..	3.3	..	..	..	..	..
6.1	..	..	3.7	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8.8	4.6	..	6.3	..	..	4.9	..	..	3.9	..	..	3.2	..	..	..	..	..
10.3	6.2	..	7.8	3.7	..	6.4	..	..	5.4	..	..	4.6	..	..	4.0	..	..
11.4	7.3	..	8.8	4.8	..	7.4	3.5	..	6.4	..	..	5.6	..	..	5.0	..	..
5.8	..	..	4.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7.9	5.5	..	6.1	3.7	..	5.0	..	..	4.2	..	..	3.6	..	..	3.1	..	..
9.1	6.8	..	7.3	4.9	..	6.1	3.8	..	5.4	3.0	..	4.7	..	..	4.3	..	..
10.0	7.7	..	8.1	5.8	..	7.0	4.7	..	6.2	3.9	..	5.6	3.3	..	5.1	..	..
5.3	3.3	..	3.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7.1	5.6	..	5.6	4.1	..	4.7	..	..	4.1	..	..	3.5	..	..	3.1	..	..
8.1	6.6	3.9	6.6	5.2	..	5.7	4.2	..	5.1	3.6	..	4.5	..	..	4.1	..	..
8.8	7.4	4.9	7.3	5.9	3.4	6.4	4.9	..	5.7	4.3	..	5.2	3.7	..	4.8	3.3	..
4.7	3.0	..	3.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6.4	5.3	..	5.2	4.1	..	4.3	..	..	3.8	..	..	3.2	..	..	..	..	..
7.3	6.2	4.4	6.0	5.0	3.2	5.2	4.1	..	4.7	3.6	..	4.2	..	..	3.9	..	..
7.8	6.8	5.2	6.6	5.6	4.0	5.8	4.8	..	5.3	4.3	..	4.8	3.7	..	4.6	3.4	..
3.9	..	..	3.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6.4	4.8	..	4.6	3.8	..	3.7	..	..	3.3	..	..	..	..	..	..	..	..
6.5	5.7	4.4	5.4	4.7	3.4	4.6	3.8	..	4.2	3.4	..	3.7	..	..	3.4	..	..
7.0	6.3	5.1	5.9	5.3	4.1	5.2	4.5	..	4.8	4.0	..	4.3	3.5	..	4.0	3.2	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4.8	3.9	..	3.9	3.0	..	..	..	..	..	..	..	..	..	..	..	..	..
5.0	5.0	3.8	4.7	4.1	..	3.9	3.1	..	3.5	..	..	..	..	..	..	..	..
6.1	5.7	4.7	5.2	4.7	..	4.5	3.8	..	4.1	3.5	..	3.6	..	..	3.4	..	..

lated by the formula $p = 100 \left[\sqrt[n]{\frac{S+L-A}{F+L}} - 1 \right]$, where p = compound interest rate, n = number of

rotation, S = stumpage value at n years; L = cost of land; F = cost of formation; and A = administration and taxes in n years at 6 per cent compound interest. Five cents per acre annually for administration (including fire protection) and one cent on the dollar (full valuation) annually

st of land, and no cost of formation of stand.
st of land, and \$5 cost of formation of stand.
st of land, and \$5 cost of formation of stand.
st of land, and \$10 cost of formation of stand.
st of land, and \$10 cost of formation of stand.
st of land, and \$15 cost of formation of stand.

NOTE. As a matter of fact calculations such as these are often misleading.

Forest Service has used this method of indicating the most profitable rotation assumption that money must be borrowed at 6%. At best it is an approximation e it is difficult to answer the financial rotation problem in advance with so many lent variables. According to the formula used, the equation would work out for rs as follows:

$$p = 100 \left(\sqrt[50]{\frac{\$99 + \$5 - \$29.04}{\$5 + \$5}} - 1 \right) = 100 \left(\sqrt[50]{\frac{\$74.96}{\$10}} - 1 \right) = 4.1\%$$

he value of the land is added at 50 years as it is assumed still to be worth \$5.00. e 7, which follows, illustrates a method of determining the financial rotations* stern white pine in common use in the United States. In this case the most ble rotation is 50 years and the result is more exact, according to the soil rent , than in the preceding equation.

rest Mensuration of the White Pine in Massachusetts, 1911. (State Forester, 1, p. 26.)

TABLE 7. The Financial Rotation of White Pine.

(Money valued at 4 per cent; value of land, \$4 per acre; cost of planting, \$10 per acre.)

AGE OF STAND (YEARS)	Gross Returns (Stumpage Value).	EXPENSES AND INTEREST.										Gross Profit.
		TAXES.		COST OF PRODUCING.		ON TIMBER.		ON LAND.				
		Annual for Five-year Periods.	Amount paid in Taxes.	Accrued at 4 Per Cent Interest.	Without Interest.	With Interest.	Interest on Value of Land Accrued.	Cost of Plant- ing and Ac- crued Interest.	Total Investment without Interest.	Total Investment and Accrued Interest at 4 Per Cent.		
25	\$ 40.50	\$ 540	\$ 2.70	...	\$ 1.50	\$ 2.17	\$ 6.66	\$ 26.66	\$ 11.50	\$ 35.49	\$ 29.00	
30	75.00	1,000	2.70	\$ 3.03	1.80	2.90	8.97	32.43	14.50	47.33	60.50	
35	195.20	1,269	7.70	9.32	2.10	3.82	11.78	39.46	19.80	64.38	175.40	
40	262.40	3,498	14.04	18.47	2.40	4.92	15.20	48.00	26.40	86.50	230.00	
45	324.80	4,330	31.53	42.16	2.70	6.25	19.36	58.41	44.23	126.18	280.57	
50	465.00	6,200	53.18	75.76	3.00	7.90	24.43	71.06	66.18	179.15	398.82	
55	505.50	6,740	84.18	127.04	3.30	9.90	30.58	86.46	97.48	253.98	408.00	
60	532.00	7,080	117.88	192.60	3.60	11.35	38.08	100.79	121.48	342.82	410.52	
65	566.00	7,548	153.28	281.32	3.90	15.18	47.20	127.98	163.28	471.68	402.72	

According to Mattoon, the object of management with cypress should be "to the highest financial returns from the class of land involved . . . and the consequent yield of the most valuable species." His conclusion is that a 60-year rotation (the object of raising poles) would be the most profitable age at which to cut.*

In a recent calculation for Douglas Fir, Quality II, Hanzlik indicates a 70-year financial rotation in the Western Cascades.

TABLE 8a. Soil Expectation Value for Douglas Fir, Quality II Site Western Cascades.

THINNINGS (PER ACRE).									
Years from now.	No. Trees Removed in Decade before Final Cut.	Average D. B. H. of Trees Removed.	Contents of Average Tree.	Total Volume Re- moved as Thinnings in Decade before Final Cut.	Value of Thinnings.				
30	200	4	1.5 cu. ft.	300 cu. ft. 3.8 cds.	\$0.50 per cd.				
40	113	6	6.9 "	780 cu. ft. 9.8 cds.	1.00 "				
50	62	8	13.0 "	806 cu. ft. 10.0 cds.	1.50 "				
60	25	10	22.0 "	550 cu. ft. 6.9 cds.	2.00 "				
70	15	12	180 B. F.	2,700 B. F.	7.00 per M				
80	7	13	260 "	1,820 "	8.00 "				
90	5	14	320 "	1,600 "	9.00 "				
100	2	14	350 "	....	....				
110	2	15	400 "	....	....				
120	2	15	430 "	....	....				
130	2	15	460 "	....	....				
140	..	..	..	....	....				

(Continued on page 51.)

* Mattoon, W. R., The Southern Cypress (Forest Service Bulletin, No. 272, 1915,

TABLE 8a. Soil Expectation Value for Douglas Fir, Quality II Site Western Cascades—Continued.

Total Value of Thinnings in Each Decade.	No. Trees Per Acre Before Thinning.	D. B. H. of Average Tree.	Height of Average Tree.	Final Yield Per Acre Each Decade.	Average Annual Growth Per Acre Each Decade.	Probable Future Stumpage Values.	Total Value of Final Yield at Various Rotations Per Acre.	(Se) Expectation Value Govt. Forest 3% Comp. Intl.	Yrs.
In.	Ft.			3,230 cu. ft. 40.4 cds.	150 cu. ft.	\$ 1.00 per cd.	\$ 40.40	\$ 11.70	30
\$ 1.90	625	6.3	34.5						
9.80	425	8.4	76.5	12,000 B. F.	222 "	5.00 per M	60.00	11.68	40
15.00	312	10.6	90.5	21,500 "	950 B. F.	6.00 "	120.00	23.08	50
13.80	250	12.5	100.0	32,000 "	1,150 "	8.00 "	256.00	36.08	60
18.90	225	13.9	108.0	41,500 "	950 "	9.00 "	373.00	39.28*	70
14.60	210	15.0	114.0	50,000 "	850 "	10.00 "	500.00	38.93	80
14.40	203	15.8	120.0	58,000 "	800 "	11.00 "	638.00	38.78	90
....	198	16.4	126.0	66,000 "	800 "	12.00 "	792.00	36.68	100
....	196	16.9	132.0	74,000 "	800 "	12.00 "	888.00	31.08	110
....	194	17.3	137.5	81,000 "	700 "	13.00 "	1,053.00	28.33	120
....	192	17.6	143.0	86,500 "	550 "	13.00 "	1,125.00	25.33	130
....	190	18.0	148.0	91,500 "	500 "	14.00 "	1,280.00	21.20	140

on present National Forest Practice and Sales Regulations in Douglas Fir Region.

Formation—nil.

Expenses—.20 per Acre.

—3% per Annum (comp.).

Yield—35% of Gross Receipts. Rev. in Forestry Quarterly, Vol. XII, No. 3, pp. 440-51.

$$+ Ta \times 1.0p^r - a + \dots Tq \times 1.0p^r - a - C \times 1.0p^r - E$$

$$1.0p^r - 1$$

Final Choice of a Rotation. The object of the owner will always be principal factor in the choice of a rotation. This object may vary some- according to whether the owner is a state, a company, or an individual.

Financial Rotation indicated at 70 yrs.

The length of the rotation will depend also on whether this principal of management is the direct production of timber or the indirect use of the use of the forest for recreation or watershed protection. Since the use of aeroplanes has become so general in war, the French attach considerable importance to the value of frontier forests as a screen to the movement of troops. This is but an illustration of the indirect protective value of forests which under exceptional circumstances would influence the choice of a rotation and system of cutting. It is safe to lay down as a general principle that where the indirect benefits of forests are of greater moment to the owner than the mere production of timber, the rotation is usually lengthened. In a forest park such as Fontainebleau, near Paris, or in the famous Wald near Vienna, the rotation would be longer than a sound technique would permit were the production of timber the sole object. So-called protection forests on the slopes of mountains usually have their rotations lengthened through the mere fact of being managed for protection purposes, aside from the slow growth due to soil or exposure. The silvicultural treatment followed has an important bearing; sometimes this is the dominant factor, as in the case of a simple coppice of oak where the sprouting capacity increases rapidly after 50 or 60 years. With naturally regenerated oak high forest the maximum limit may be set to the length of rotation because of the loss of off in seed production. But if the main object of management is timber production, a rotation based on the maximum income in wood material is indicated if this coincides with the (forest rent) financial rotation. If they do not coincide as seldom happens, then a compromise must be made between the owner on the basis of the best available data. According to Schlich

"In the first place, the financial (soil rent) rotation should be determined as that which gives a true expression of the economic value of the management; then, it should be ascertained in how far the objects of management demand a departure from the financial rotation; lastly, the financial loss involved in such a departure should be determined so that the proprietor may have a clear conception of the payment which he is obliged upon to make in order to realize his special object."

As Schlich well points out, the drawbacks to purely financial rotations, impoverishing the soil must be borne in mind. Quantitative (economic) financial rotations (which have been discussed at length) depend on more complete yield and market data than is usually obtainable during the early stages of forest management. It is for this reason that this type of rotation has often been replaced in the United States by tentative technical or biological rotations; an authority such as Endres** refers to these latter rotations as being of mere "historical interest" because of the development in Germany of detailed yield and market data.

57. Summary of Principles Affecting Length of Rotations. Let us now summarize some of the principles upon which the determination of the rotation depends:

* Schlich, William, *Manual of Forestry*, Vol. III, 1911, p. 202.

** Endres, Max, *Lehrbuch der Waldvertrechnung und Forstatik*, 1895, pp. 2.

The length of rotations tends to increase on poor sites and decrease on good sites. (Yet in North Germany there are short rotations on pure

In financial rotations (soil rent) the lower the interest rate, the longer the rotation allowed by the calculation, but other factors must be considered.

An increase in the quality of product yielded lengthens financial rotations. Quantitative rotations will vary according to the utilization in the stand according to the log rule used, and according to the basic class of product (per cubic, board feet, poles, ties, etc.).

When the mean annual growth begins to decrease, the per cent of rotations is reduced; danger from defect limits the length of rotation with such species as the spruce and fir.

Rotations vary according to the ownership and purpose, silvicultural treatment, market and logging conditions, site, species, as well as with the character and condition of the stand. We must never forget that the world is producing building timber.

With more intensive economic conditions there is always a tendency toward shorter rotations; with extensive economic conditions longer rotations are required (with long cutting cycles).

In choosing a rotation technical, silvicultural, quantitative and financial considerations should be summarized before making the final decision. But the interest of the owner must always have the dominant interest in deciding what rotation to choose.

Once a preliminary rotation has been established, modifications are necessary with economic changes.

In the United States Roth advocates a rotation no longer than necessary to produce the kind of material desired and a reasonable income as well as to maintain the fertility of the land. He believes in calculations to show the best net financial (forest rent) yield. He correctly emphasizes that in the future, market sizes will be smaller and rotations will be reduced by thinnings and by efficient planting. Roth also favors short rotations where open stands otherwise suffer from insects and fungus.*

The author dismisses the rotation of maximum volume and the rotation of forest rent as the former based on false public economy, the latter because based on false mathematical basis; there remains for discussion only the rotation of maximum *soil rent* and technical rotation, the latter being defined as that which produces continuously the greatest quantity of the most valuable marketable wood under the given conditions of site and market. These two rotations are in many cases identical (coppice) Financial rotation depends in the first place on the choice of the rate per cent."

Knagel first divides the customary European rotations according to whether (1) small or (2) large tracts. The average rotation for small tracts (presumably intensive management) he shows is 10 to 20 years less than for large tracts. Then he distinguishes between (1) plains and foothills, (2) intermediate mountains, and (3) high mountains; within each topographic subdivision a further differentiation by species. But these are not of real scientific value because the basis for the rotation under the different

*Roth, Filibert, *Forest Regulation*, 1914, p. 117.

Review by Fernow of article by Pilz (*Forest Quarterly*, Vol. 2, 1904, p. 183).

conditions is not given. In the plains the rotation might be purely on the basis of present while in the mountains perhaps soil protection was of paramount importance determining when to cut. His averages for small tracts of spruce are (1) 60-80 in the plains and foothills, (2) 60-100 in the intermediate mountains, and (3) 100 years in the high mountains. Roth* says more specifically that the,

"Rotation for largest volume in Germany and for fair to good site (site II) is as follows: pine 60 years, spruce 90-100 years, beech and balsam 110-120 years. This is in very nicely with the technical rotation for these species."

The writer agrees thoroughly with Schiffel's conclusion that,

"Today we know that a careful survey and critical investigation of stands as regards their silvicultural condition, a comparative observation of their development, and proper selection and attention to their growth of species furnishes a much surer basis for securing maximum revenue than Pressler's formula receipts."

Yet especially in American Forest Management, a forester cannot follow ideal methods, but must weigh the results with the cost. An ideal might be to have complete fire protection, but the ideal may be shattered by considerations of cost. Will it pay?*** must be answered before regulation measures are finally decided upon.

It is too early to try to average or classify rotations established in the United States. In the majority of cases they have not been tried out so far as they are purely theoretical rather than empirical. Extensive forestry requires much longer rotations than will prevail later on because of the extreme conditions sufficient differentiation has not been made. With a possible shortage in the world's timber supply, short quantitative rotations for maximum production are predicted; and quite probably in the tropics under favorable growing conditions the rotations may be one-half to one-third of those required in the temperate zone.

58. Quiz. Define the maximum forest rent rotation.

Review definitions of capital and value.

Write and explain the forest rent formula.

How does it differ essentially from maximum soil rent? from economic rotation?

Under what conditions are soil rent rotations preferable?

Why is the answer based on mean annual rather than current annual maxima?

Is this rotation applicable to national forests? to woodlots in New England? to southern pineries?

What are the difficulties to its wider use?

How would the rotation be affected by the omission of thinnings? by heavy immediate returns? by natural regeneration? by heavy forestation expenses?

How do large soil values affect the result?

How does price increment and quality increment affect the result?

Write and explain the soil rent formula.

How do you arrive at the culmination of a forest rent and soil rent rotation for different conditions?

Give a simplified form of the soil rent formula.

How important is the rate of interest used?

* Review by Fernow of article by Schiffel entitled *Rev. Reinertragslehre in der G. A. Schiffel (Forestry Quarterly, Vol. 2, 1904, p. 186).*

** Recknagel, A. B., *Certain Limitations of Forest Management* (P. S. A. F. V. 1912, p. 227). Recknagel has done a great deal for American Forest Management publishing widely on technical forestry, much of it from reliable German sources.

rate should be chosen?
What importance is the final yield upon the result? (The study of the translation
addresses may be made optional.)
What importance on illustrations of financial rotations established in the United States.
What should be the chief factor in the choice of a rotation?
What is the choice of a rotation.
What are some rotation variables and axioms?
What are some rotations established in Europe.
What contrast these with those suggested for the United States.
What student should be given rotation problems to work out in order to fix in his mind
What relative length of rotations for given conditions according to whether they are
What, economic, etc.

CHAPTER VI

THE NORMAL FOREST

59. Definitions of Normal Forest, Normal Increment.—*Normal Forest*—A standard with which to compare an actual forest to bring out its deficiencies in sustained yield management; the conception of an ideally regulated or organized forest; a forest with normal increment, normal age classes in size and distribution, and normal stock.

Normal Increment—The best increment attainable by given species on given sites.

Normal Age Classes—The presence of a complete series of age classes which permit annual or periodic fellings to be made.

Normal Growing Stock or Normal Stock—The amount of material represented by the stands in a normal forest; practically, the contents of the age classes as represented in normal yield tables.

The equalization period is the period during which it is planned to attain approximately normal stock conditions. (G., *Einrichtungszeitraum*.)

60. Discussion of the Normal Forest. The difference between the normality of the normal forest and that of the normal yield table must be clearly understood. The normal forest is merely an ideal difficult to attain, while the yield of the normal yield table is *always* attainable since it is based upon averages of actual measured stands. Even such a forest as the Silberberg (cited by Roth) falls far short of being normal even from the sole view-point of normal age class distribution. Nevertheless the normal forest will always prove of value as a basis for comparison.

The normal forest requires:

- (1) A normal distribution of age classes and a complete cutting system which usually leads to:
- (2) A normal increment.
- (3) A normal growing stock.

These have already been defined and will be discussed in detail later.

A forest may be referred to as *under-stocked* when it has a growing stock less than the normal growing stock; or *over-stocked* when it has a growing stock greater than the normal growing stock.

61. Three Phases of Abnormality. As a matter of fact, forests are usually abnormal in three ways:

(1) *Over-stocked.* A forest past the age of maturity may have a growing volume per acre than the normal. Therefore, there will be a surplus of growing stock which must gradually be removed. This surplus must be removed because there are too many acres of the older age classes (see # 3 below).

(2) *Under-stocked.* The increment may be more than the average increment of the growing stock, because there is too large an acreage in immature stands. The yield will be less than normal. Consequently, the forester may be called upon to economize by cutting less than the increment to accumulate a normal

growing stock. This is particularly true where the yield must be board feet for sawmill purposes, because lumbering trees less than a size is usually uneconomic. The accumulation of growing stock to a deficit is often secured by adopting a rotation that is more than required to grow the stand or by cutting less than the estimated yield.

Volumes Normal, but Age Classes Abnormal. This is the worst form of abnormality because the entire forest may be practically of one age class. A manager should conceive of one age class as allowing a variation of 20

This is especially unfortunate because it will necessitate such a long time before lumbering can take place again. It precludes the maintenance of a sustained yield. It represents the probable situation in the United States where our virgin timber is exhausted by destructive logging.

A Normal Distribution of Age Classes. This requires that separate age classes exist which will mature during each year or period of the rotation. Age classes must occupy areas whose yield will equal the same relative part of the total yield of the working group for the entire rotation that their period or period bears to the rotation. In theory each of these age classes must occupy areas of equal productiveness so that if they are cut at the same age, equal annual or periodic yields are obtained. The basis for comparison is the yield from yield tables. If one acre of a forest yields 50,000 board feet at 100 years while another yields but 25,000 then there must be two acres of the latter for every acre of the former in order to have a normal age class distribution. Where the increment of a forest with normal age classes is only half what it should be, its age class form would be normal. It might have a sustained yield because the beneficial results of a sustained yield are not wholly dependent on full increment per acre but on well distributed age classes.

Artificial and Natural Factors Influencing Distribution of Age Classes. Unfortunately an abnormal distribution of age classes is the rule because of artificial and natural factors. The *artificial factors* are:

A full cutting series is required. A cutting series is *an aggregation of compartments (stands) in a proposed or actual sequence of cutting areas*, the series being a distribution of cutting areas for administrative reasons, or to secure a final satisfactory distribution or location of age classes, especially to avoid damage by windfall and insects due to uniformity of stand and size of cutting area. It is therefore intended to interrupt a regular sequence of age classes.

The number of age classes hinges on the number of years in each age class (usually 20 years) and on the length of rotation adopted. If the rotation is changed, the number of age classes required is modified, and the distribution which was normal in this respect for one rotation becomes abnormal for the next.

The area proper for each age class depends directly upon the total area in the working group and on the rotation and number of age classes. Consequently, areas which are normal for one rotation become at once too small if the rotation is lengthened or too small if it is shortened.

The *natural factors* are even more perplexing. There are always too or too small areas or volumes present, requiring increases or reductions in given age classes. It is for this reason that the minimum time required for the transformation of a forest to normal age classes is one full rotation. Practical considerations usually call for at least two rotations or more. As a matter of fact, the ideal is seldom, if ever, attained in age class distribution, but if it is attained and the rotation is modified because of economic conditions, the process of regulation must start over again. Accidents such as windfall, fire or unusual local demands which must be met, are contrary to the transformation to more normal conditions.

64. Normal Increment. The second requirement of a normal forest is *normal increment*. It is theoretically normal if there is maximum growth in all parts of the area for given species and sites. It is the goal of silvicultural practice. Just as in the case of age class distribution, normal increment cannot be attained until the second rotation, and not even then unless previous success has been obtained throughout the first rotation—something that is entirely impossible. Normal increment does not serve as the basis for the regulation of the cut in the first rotation, since in this case actual increment is used as a base because normal increment would not apply. Actual increment of normal or ideal stands, or even the average for the stands that are fully stocked, according to local or general yield tables, does not give the forester an idea of the growth on excess stands. The increment of existing stands must be determined in each case, and any attempt to regulate the cut, (based on the removal of surplus growing stock or on enriching a forest where the growing stock is deficient,) must be based on the study of the actual increment and not on the theoretically normal increment.

65. Normal Growing Stock. The third criterion of normality, *normal growing stock*, might be actually attained. But nevertheless it is simply an ideal, which unfortunately is often misunderstood. One writer contends that our knowledge of the forest is so indefinite and the irregularities so unending that a normal condition cannot be conceived, and that normality is therefore a delusion.* Often a forest may falsely appear to have a normal stock owing to an accumulation of volume in stands past the rotation. This phase of abnormality must be recognized especially when a very long rotation has been chosen.

There is nothing in this argument to justify throwing overboard the concept of normal growing stock. It only serves to emphasize the need for bearing in mind that normal growing stock is an ideal to steer by.

The length of rotation is especially important in affecting the normal growing stock, where the forest is to be managed on the basis of permanent production. This is true because the rotation,

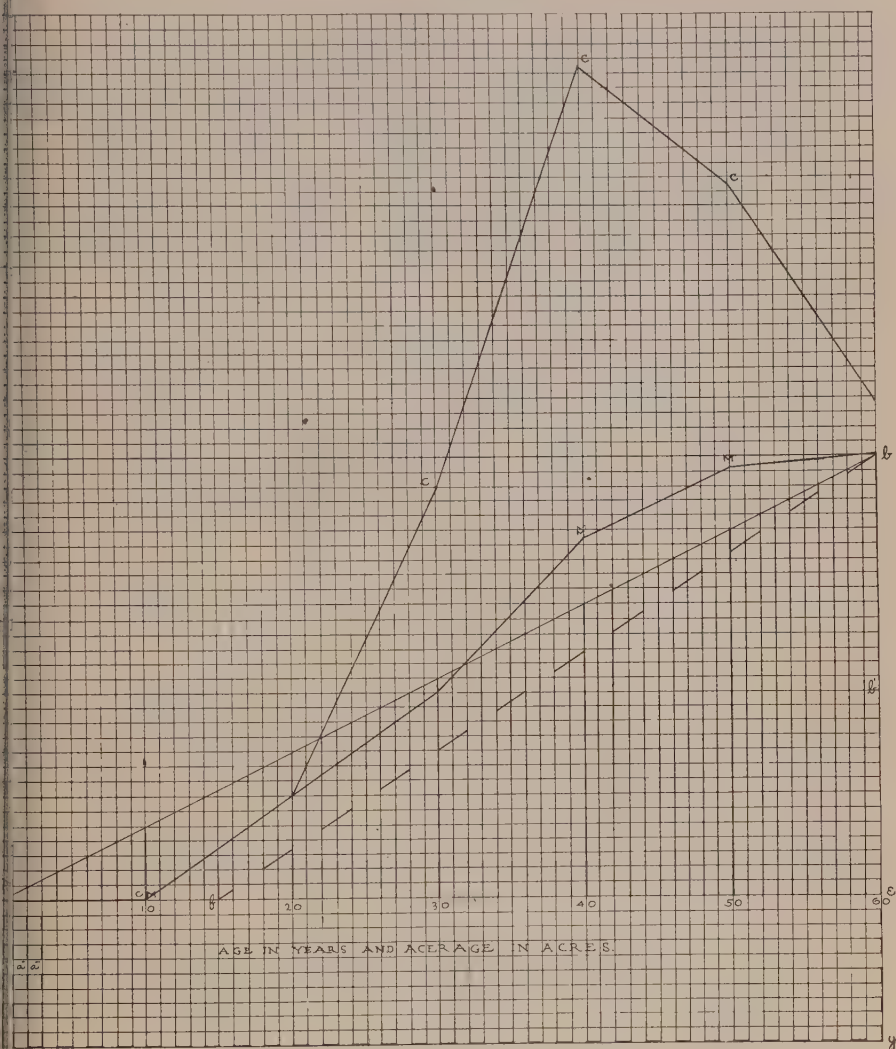
(1) Determines the amount of timber that must exist as forest capital in order to obtain a continuous yield; and

(2) Indicates whether a surplus or deficit exists in the actual forest

* Review by Fernow, entitled *Heresies Regarding Normal Stock*. (Forestry Quarterly, Vol. 14, 1916, pp. 524, 553-67.)

ement and tells whether more or less than the actual increment can

Growing Stock Formulae. To obtain a clearer conception of the forest and its normal growing stock reference is made to figure 3.



Diagrammatic Representation of Normal Growing Stock and a Comparison with Mean Annual and Current Growth for a 60-year-old Stand Sixty Acres in Area.

Forest of 60 acres is here represented as being managed on a rotation of 60 years. If the entire forest were very abnormal and contained 60 acres of mature timber, then the volume would be represented by the diagram 'e'. But let us suppose it is normal. Then there will be one acre one year old, one acre two years old,.....one acre 59 years old, and one acre

60 years old, or about half what the forest would contain if it consisted of fully mature stands. The column b' represents graphically 60 years and the column at the extreme left of the triangle represents ones growth. From this it is clear that a simple formula for normal growth stock is as follows: $G^n = \text{rotation} \times \text{m. a. i.} \div 2$ or $G^n = \frac{r \times i}{2}$

It is customary to ignore the effect of thinnings on the equation.

This formula falsely assumes that current annual growth and mean growth remain equal. The author obviously overlooked the fact that growth is not laid on in annually equal quantities, but that it varies according to the age of the tree. The fallacy lies in the assumption that current growth and mean annual growth are the same for all ages. As a result of this premise, if most of the growth is laid on in the latter half of the rotation the actual growing stock required is less than that given by the formula because the mean annual growth or proportional volume is less for the younger age classes. This is particularly true when the growing stock is measured in manufactured products, where it is almost universal that a tree has no measurable volume in board feet until it is 15, 20, or more years old.

This fallacy of assuming that growth is a straight line is shown diagrammatically in fig. 3, where a-cm-ccc-b represents current growth and a-cm-mmm-b the mean annual growth according to table 8. To correct this inaccuracy of assuming the growth a straight line ab, Moore* (P. S. Vol., VII, 1912, pp. 15-16) originated a formula which is a makeshift based on the disadvantage of the board foot rule but unquestionably it gives more conservative results in the United States than the formula $\frac{r \times i}{2}$.

His formula is $\frac{r' \times i}{2}$, where r' is the rotation minus the age when the tree becomes merchantable. In this case the tree would be (see line fb, fig. 3) merchantable at 15 years or half way between 10, when the yield is 0, and 20, when the yield is 4500 (see table 8).

The use of this formula Moore claims will give a more correct surplus or deficit when compared with the actual stock which includes only merchantable trees. He states that,

"Where the increment is known to be too low, it is unwise to try to correct the error by using r (the whole rotation) instead of r' (the difference between the rotation and the merchantable trees and the rotation). The whole rotation will give a growing stock which is actually more correct, but mathematically incorrect and hence uncertain. It may be too large or too small. It will also give too low a cut of increment in the formula and will not be counterbalanced by a high surplus."

While Moore's argument is sound his substitute formula according to H. Wolff is incorrect. The proof of this, and the correct formula, are developed graphically.

* See Schlich's Manual of Forestry, Vol. III, 1911, pp. 222-227. In intensive forestry it would make a difference in the amount of the normal stock whether it were calculated in spring before growth, in summer after growth, or in autumn after the year's cut. For American conditions this complication can safely be omitted and calculations can be standardized to correspond with the summer when the year's cut is half complete.

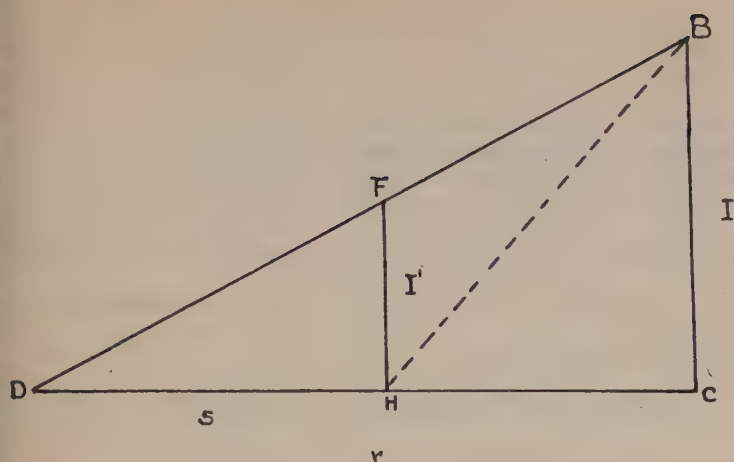


FIG. 3(a) Proof of Wolff Formula.

the triangle DBC represents the total normal growing stock on any tract including merchantable and unmerchantable (nonestimable) sized stands, DC being equal rotation age (r), and BC being equal to the mean annual increment (I) of the acreage. " I " can be more definitely expressed as the mean annual increment (i), times the rotation age (r) multiplied by the total acreage (A) divided

$$I = (i \times r) \times \frac{A}{2}$$

ie also that DH represents the merchantable age (s), and that FH is the at that age (I') of the annual acreage to be cut over. Volumes below this age estimated.

re recommends that properly, the normal stock should be figured as $I \frac{(r-s)}{2}$ or figure above to $\frac{BC \times HC}{2}$. Diagrammatically this is equal to the triangle BCH. assumes that volumes at merchantable age commence at zero.

ually the volume at the minimum estimateable age is appreciable. It is the mean annual growth times the number of years. Thus in our figure the growing stock above merchantable age (call it GN for convenience) is the trapezoid (A trapezoid) FBCH. Hence Moore's suggested formula excludes triangle FBH and gives by that much, too low a figure.

tain the correct and most convenient formula for normal growing stock above merchantable age, it is necessary to find the value of the area FBCH, in terms of I , r ,

$I = BC$; $r = DC$, and $s = DH$.

$$(1) \text{ FBCH} = \frac{FH + BC}{2} \times HC = \frac{I' + I}{2} \times r - s.$$

$$(2) I' : s :: I : r; \text{ or } \frac{I'}{s} = \frac{I}{r}; \text{ or } I' = \frac{Is}{r}.$$

(3) Substituting for I' in (1)

$$\begin{aligned} \text{FBCH} &= \frac{\frac{Is}{r} + I}{2} \times (r - s) \\ &= \frac{Is + Ir}{2} \times (r - s) \end{aligned}$$

$$\frac{I(s+r)(r-s)}{2r}$$

$$(4) \frac{I(r^2 - s^2)}{2r}$$

This is mathematically the correct formula to use, but see table 9.

67. **Illustration of Simplest Normal Growing Stock Calculations.** The values by the three different methods in any example are interesting to note, $r=60$ years, and $S=15$ years (i.e., when tree becomes merchantable). Then

(a) ordinary method: $Gn = \frac{I \times 60}{2}$ (or $i \times 30$; by (b) Moore's suggested $Gn = \frac{60 - 15}{2}$, or $i \times 22.5$; by the method (c) here recommended (after $Gn = I \times \frac{60^2 - 15^2}{2(60)}$, or $i \times 28.125$.

Assuming the mean annual increment at 60 years given in table 8, we find table 9):

$$(a) \frac{1003 \times 60}{2} = 30,090 \text{ feet B. M. per acre.}$$

$$(b) \frac{1003 \times (60 - 15)}{2} = 22,567 \text{ feet B. M.}$$

$$(c) \frac{1003 (60^2 - 15^2)}{120} = 28,209 \text{ feet B. M.}$$

68. **Yield Table Method of Computing Growing Stock.** None of the formulae are as accurate as the result obtained by adding yields from the yield table (see table 8) expressed as a formula; thus,

$\frac{10(a + b + c + d + e + \frac{f}{2})}{r} = \text{normal stock per acre, where } a = \text{yield at 10 years, } b \text{ at 20 years, etc.}$

10 years	20 years	30 years	40 years	50 years	60 years
(a)	(b)	(c)	(d)	(e)	(f)
0000 ft.	4500 ft.	13900 ft.	32800 ft.	49100 ft.	60200 ft.

FIG. 4. Diagrammatic Scheme of the Yield Table Yields.

Referring to Figure 4, let us conceive of our normal forest composed of six square areas, each 10 acres in extent; with the assumed rotation of 60 years, each square will then correspond to 10 years of the rotation. In computing the normal growing stock formula, it is clear that each figure from the normal yield table must be multiplied by 10 to secure the normal growing stock for a forest of 60 acres. Half the yield in square (f) is taken because cutting is going on in the oldest age classes; consequently all the timber will be standing the first of the decade but none of it will have expired.

69. **Illustration of Calculating Normal Growing Stock from Yield Table.** An illustration of the calculation of normal growing stock by the yield table method is given for site (I), white pine in New Hampshire managed on a rotation of 60 years. The yield assumed is as follows*:

* Frothingham, E. H., White Pine Under Forest Management (Forest Service Bulletin No. 13, 1914, table 6, page 23).

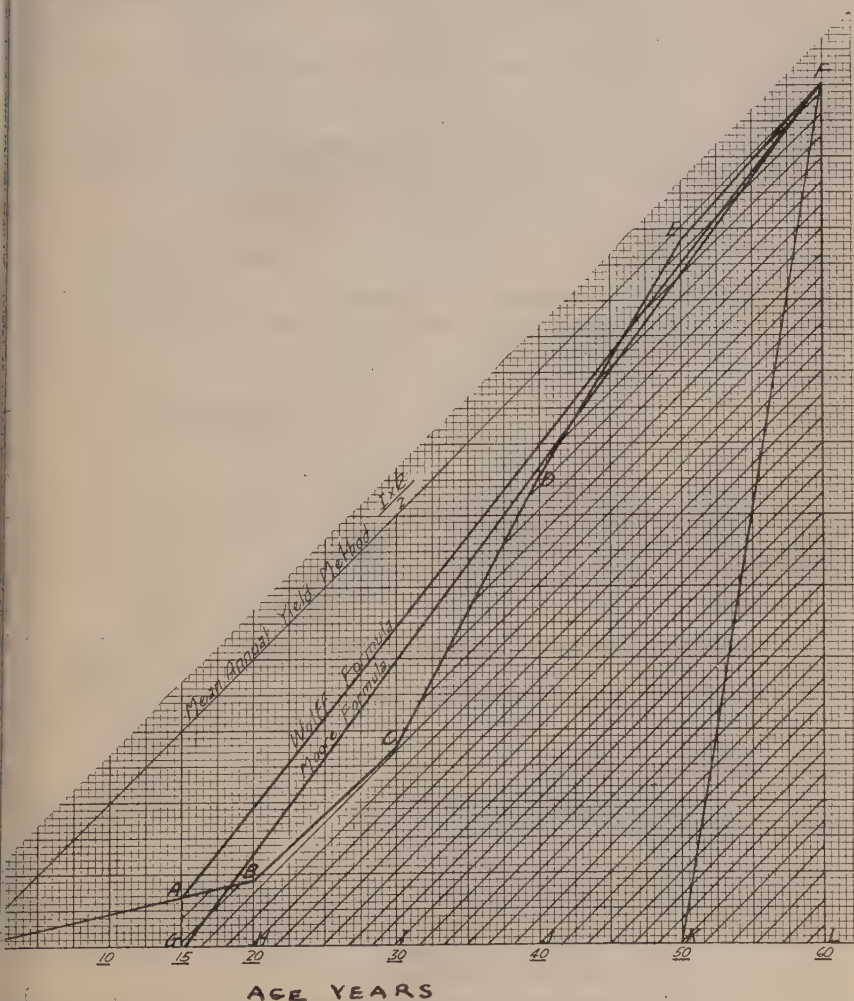
TABLE 8. Yield of White Pine in New Hampshire.

Year	Lumber yield per acre, board feet		Mean annual increment board feet	Current annual increment, board feet
10	0000 a	(See Fig. 4)	0	0
20	4500 b		225	225
30	13900 c		463 plus	940
40	32800 d		820	1890
50	49100 e		982	1630
60	60200 f		1003 plus	1110
(70)	(69900)		...	970

the formula we have,

$$-13,900 + 32,800 + 49,100 + \frac{60,200}{2}) \text{ board feet} = 10(130,400) = 1,304,000 \text{ board}$$

feet or 21,733 plus per acre. When a rotation of 60 years is assumed, the growing stock formula result may be figured for an acreage equal to the number in the rotation.



APPENDIX F. Graphic Comparison of Normal Growing Stock Formula (for text, see Appendix F).

70. **Comparison of Normal Growing Stock Formulae.*** In the following the normal growing stock has been calculated by the following formulae: column 1, accurate yield table method; column 2, mean annual increment often inaccurate in board foot units; column 3, mean annual increment, where (after Moore) rotation is taken as total age minus age when tree is merchantable (in this case tree is merchantable at 15 years); column 4, same as 3 but using the Wolff corrected formula (§ 66-67) which should be used instead of 3; it gives higher figures than the formula but is more conservative than 3.

TABLE 9. Normal growing stock in board feet per acre for rotations of 20 to 60 years by different formulae (figures evened off).

1 Rotation years	2 Yield table method	3 Mean annual increment (Board feet per acre of forest)	4 Mean annual increment (using r')	5 Wolff formula
20	1,125	2,250	562	984
30	3,816 plus	6,950	3,475	5,209
40	8,700	16,400	10,200	14,094
50	15,150	24,550	17,185	22,340
60	21,733 plus	30,090	22,567	28,209

From the foregoing it is apparent that the normal growing stock in board feet calculated on the basis of r' (after Moore) is closer to that given by the yield table method than the result if figured by the usual $r \times i$ formula or by the Wolff method of Moore's r' . This is discussed at length in Appendix F.

The use of another formula** is advocated for normal growing stock in selection forests, which Munger claims is simpler and perhaps sounder than the formula just (m. a. increment = i) described. It is based on the theory that the base area (figure 3) represents the length of the cutting cycle and the rectangles a' , a'' , and a''' the amount left per acre after a heavy "selection" cutting. Munger uses the following formula. The formula is as follows:

$$G_n = \frac{i \times cc}{2} + \text{Reserved timber per cutting area} \times \text{number of areas. Total growing stock.}$$

Following arguments are given in favor of this formula:

- (1) It can be applied equally well to cubic feet or board feet.
- (2) It obviates the use of the length of the rotation "a very uncertain and measureless quantity in a forest cut by the selection system."
- (3) It does away with the necessity of deciding when a tree is to be estimated as merchantable timber which is so vital to the Moore or Wolff formulae.

71. **Illustrations of Munger Formula.** Suppose** that a virgin stand of yellow pine averaged 16,000 board feet per acre and that three-fourths of it is so-called "selection" cutting (thus leaving a residue of 4,000 per acre) and that the current annual increment on this 4,000 feet is 100 feet. Let us assume a cutting cycle of 50 years and a rotation of 200 years. Then,

"At the end of a cutting cycle each coupe (cutting area), when ready for cutting, contains its original 4,000 board feet plus the 50 years of increment ($50 \times 100 = 5,000$) or a total of 9,000 feet."

Taking I as equal to the "annual increment of whole forest (annual increment of each coupe $\times$ rotation)," then applying the formula we have,

* A similar comparison is given in Schlich's Manual of Forestry, Vol. III, p. 225, but in cubic feet not reduced to a per acre basis.

** Munger, T. T., A Formula for Normal Growing Stock in Selection System (P. S. A. F., Vol. X, 1915, pp. 18-21.

$\frac{5,000 \times 50}{2} + (4,000 \times 50) = 325,000$ board feet on 50 acres or $\frac{325,000}{50} = 6,500$

With $i = 100$ feet the result would be (with the formula $\frac{i \times r}{2}$) using of

current increment for i , $\frac{100 \times 200}{2} = 10,000$ per acre. For a more critical and discussion of this formula, see Part II, Chapter X.

Flury's Normal Stock Formula with Illustration. Flury* suggests a reducing (Constant) to read $G_n = c \times r \times i$ instead of the usual $G_n = \frac{r \times i}{2}$. This idea is to substitute a constant reducing factor for each decade instead of using $\frac{i \times r}{2}$ for all ages.

Becknagel has worked out an excellent illustration** which shows what degree of yield can be obtained. But if great accuracy is required, why not use the yield table to start with, since the calculation takes but a few minutes. Where no yield is available, the value of c could not be figured; hence the method is not of great value.

A Normal Stock Calculation in Lodgepole Pine. A method of calculating normal growing stock in a lodgepole pine forest is illustrated by the table*** which

10. Real and Normal Growing Stock and Periodic Annual Increment on the Bernice Division, Deerlodge National Forest, Mont.

Age	Area	Normality	Growing stock		Periodic annual increment		Yield at the age of 140 years ¹
			Real	Normal	Real	Normal	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>Acres</i>		<i>1,000 cu. ft.</i>	<i>1,000 cu. ft.</i>	<i>1,000 cu. ft.</i>	<i>1,000 cu. ft.</i>	<i>1,000 bd. ft.</i>
rs	1,570	0.67	95	402	9	40	16,662
rs	9,742	.69	1,815	1,205	121	80	106,476
rs	5,511	.73	2,293	2,544	121	134	63,448
rs	7,559	.66	5,687	5,089	284	254	78,920
rs	1,412	.67	1,731	8,168	65	308	15,058
rs	4,887	.49	5,747	10,713	136	254	38,000
rs	1,928	.40	2,267	13,123	42	241	12,215
rs	2,448	.30	2,468	14,998	31	187	11,633
rs	2,092	.20	1,582	16,872	18	187	6,628
rs	3,040	.20	2,481	18,211	18	134	9,631
rs	396	.20	342	19,283	2	107	1,254
o (average 30 years):							
nantable ..	17,761	.35	28,671	61,062	57	147	.....
essed ..	4,145	.10	1,890	.....	...	...	.....
al	62,491	...	57,069	171,670	904	2,073	.....

normal yield, 15,840 board feet at 140 years on sites of average quality; 78.7 per cent overstocked; 20.5 per cent of area understocked; 0.8 per cent of area normally stocked.

For a more complete discussion, see review by Fernow (Forestry Quarterly, Vol. 9, 1915, pp. 108-113).

Becknagel, A. B., Forest Working Plans, New York, 1917, p. 11.

Ferguson, D. T., Utilization and Management of Lodgepole Pine in the Rocky Mountain Forest Service Bulletin 234, 1915, pp. 36-39). The columns have been numbered to facilitate reference in this text.

The figures for real growing stock (4), the present total stand were obtained by multiplying the normal stand (normal according to an empirical yield table) per acre for each age class (as given in table 9, Forest Service Bulletin 154) by the "normal" (3) or per cent of stocking, a figure which was multiplied by the actual area occupied by each age class. In the case cited in the preceding table the forest comprised 100 acres of productive timber land, the rotation was 140 years (divided into 14 periods of 10 years each) so the normal area per age class was $\frac{62491}{14} = 4,463.6$ acres.

The normal growing stock for the 10-year age class was then found by multiplying the normal yield (from table 9, Forest Service Bulletin 154) by this normal area—figures 90 cu. ft. $\times 4,463.6 = 94,671$, or 95,000 cu. ft. This simple method of computation is of value under the extensive conditions prevailing in the West.

74. Importance of Normal Growing Stock in the United States.—The reason why the computation of normal growing stock is important—especially in extensive American forest management—is because of its usefulness in forest regulation by volume formula methods, which may often be sufficiently accurate for early regulation.

This normal forest, which we have been discussing, in theory might be attained on an area of definite size and for a rotation of given length. At the lapse of a complete rotation, if all other considerations were sacrificed to the attainment of a proper series of age classes, and provided that the forest was free from accidents or injury to the forest could be completely excluded from our calculations throughout the entire rotation, and provided further that no change in the existing rotation need be made because of different economic conditions. Because of the impossibility of attaining normal age classes, even if these sacrifices were made, the proper policy is to build up as good an age class series as possible by working groups and let the distribution of the total forest area take care of itself. The gradual attainment of normal age class distribution involves cutting stands before or after the rotation. This is not so commercially undesirable unless carried to such extremes as to result in serious volume loss results. Such sacrifices are usually warranted to a certain extent in regulation, although it must be recognized that a later change in the length of the rotation requires a rearrangement.

75. Quiz. Distinguish between normal forest and normal yield table. What must a forest possess to be normal?

How are forests usually abnormal?

Discuss normal age classes: how is the distribution affected by artificial and natural factors?

Discuss normal increment.

Discuss normal growing stock.

Explain the growing stock formulae $G_n = \frac{r \times i}{2}$; why is it faulty?

Should growing stock be calculated in spring, summer, or autumn?

Which is the better formula for board feet $\frac{r \times i}{2}$ or $\frac{r' \times i}{2}$ or $\frac{i(r^2 - s^2)}{2r}$?

Explain the formula $\frac{i \times cc}{2}$ plus Res. per cutting area $\times$ number of acres.

Why is it useful? Its drawbacks (see chapter X)?

- n the calculation of growing stock by the yield table method.
- s this most accurate?
- s the yield multiplied by 10 in the formula?
- s $\frac{f}{2}$ used?
- n a 60-year rotation is a normal forest of 60 acres assumed?
- is Flury's constant?
- s it computed?
- is its advantage over the yield method?
- are normal growing stock calculations important even in extensive forestry?

CHAPTER VII

REGULATING THE CUT

76. **Definition and Aims of Regulating the Cut.** Regulation of the narrower sense means *the fixation in advance of the annual or periodical growth which in the normal forest would be equivalent to the annual growth** (G., bestimmung, ertragsbestimmung; F., fixation de la possibilité).

The broader aim of regulating the cut is three fold:

(1) To cut each stand at rotation age (maturity) and secure the maximum required product. This is largely economic.

(2) To cut about the same amount of material of the most valuable product each year or decade. This is economic and financial and important.

(3) To reproduce about the same area each year or decade. This is the aim of the preceding paragraph 1.

(1) If each stand is cut at maturity, it will probably benefit the stand in the expense of the future of the forest because no progress would be made towards a regular yield which ultimately looks for regular age class distribution. On the other hand, if stands are cut when *very* overmature or immature, costly silvicultural sacrifices may result.

(2) If the present volume output is considered of first importance, it may mean a sacrifice in future orderliness for present immediate regularity of output. For a forest that has been impoverished proper regulation demands that the stock be gradually built up; while a forest with excess stock should have this excess gradually reduced. This may decrease or increase the present output but need not seriously interfere with *its regularity*.

(3) Unless a reasonably uniform area is reproduced each year or decade the ultimate normal distribution of age classes (and hence of the cut) will be defeated. To reproduce equal areas each year or decade is the *least important immediate object* but the *most important ultimate one*.

77. **Basic Policy in Regulating the Cut.** The first step in regulating the cut is naturally to take stock and to divide the forest into timber productive and non-productive types as well as into management subdivisions. The second step is to obtain accurate growth data on the productive areas.

Before fixing the annual cut—one of the aims of regulation—the following general principles should also be recognized as basic:

(1) The forest should be managed so as to furnish the maximum quantity of the kind of material required by the owner. Where desired, scenic and game protection working groups may be excepted from regular commercial management.

* In the normal forest the current growth is the same as the mean annual growth. Before commencing chapter VII the student should read "Studies in French Forestry" pages 243-260, so as to have the modern working plan clearly in mind.

Other things being equal, cutting should be directed to the over-mature stands and age classes.

Forest management must first provide for the prolongation and per-son of the timber supply—sustained *forest* production—needed by industry and for the stabilization of labor, if this can be done without too heavy sacrifice of technical aims.

The technical aims of every working plan lead to (3) above and may be: proper distribution of age or diameter classes, normal growing conditions and a proper silvicultural condition ensuring suitable regeneration and situation of the forest as a whole. Under certain conditions fire or insect protection may be the chief technical aim.

These aims must be carefully weighed and correlated.* But it must be realized that no regulation or organization of a forest has the slightest chance of success unless it is based upon sound basic silviculture, because regeneration and forest production—both dependent on sound silviculture—must be successful or there will be no real forestry.

Our extensive western forests, which must at present often be logged by operations capable of maintaining and operating large capacity plants with continuous feeders, there is usually presented the following problem which is especially difficult to compromise without serious sacrifices:

Devastate mature and over-mature timber rapidly to avoid loss from decadence with a consequent heavy cut during the first cutting cycle, a yield which cannot be maintained after the store of ripe timber is harvested. Proper age class distribution will be delayed for a considerable period. This is not forestry.

Cut off mature and over-mature timber gradually assuming a considerable and increasing loss from decadence but aiming at a yield during the cutting cycle equal or nearly equal to the original cut. The age class distribution will be secured at an earlier date than if (a) is adopted as the normal cutting policy. The *actual* losses from decadence are often oversized.

Compromise between (a) and (b) so as to avoid part of the loss from decadence necessitated by (b) but obviating the serious hiatus of cut required

This problem must be decided in each case before the details of regulation are intelligently worked out. Nor must the silvicultural requirements for regeneration be lost sight of. With plan (b) certainly regeneration is surer than with (a) in difficult soil conditions such as often occur in the Pacific. The administrator should always remember that *stability of production* is more important than to save timber that *may* be lost.

Speaking in terms of intensive selection forests in France, Biolley** argues that since the cut depends on the amount of the forest crop, it is better to

—
redge, I. F., says (J. of F., 1920, pp. 284-291) the aims of management plans in national forests of the Southern States are: maximum production of merchantable timber, permanence of local industries and forest labor, salvage of deteriorating timber, reforestation of mistreated areas, regulation of cut (by stand method).

Biolley, already cited, p. 56-57.

decide on the *cut* after it is seen what the *amount* of the crop really is says:

"The growth, which is the fruit of the treatment, can only be known after the is disclosed; the yield can thus only be a prediction of the harvest (more strongly justified) for a very short lapse of time It is useless and an error to make predictions for a long time ahead; it is even worse to fix a yield for a rotation as is done, even if it is subject to revision every twenty years, for the yield-decides the hands of the forester, and substitutes for the worry of the silvicultural aim cutting, preoccupation over the volume which it is forbidden to exceed or obliges to reach; moreover, the *treatment* (the essential thing) gives way to regulation cannot be the objective."

What Biolley wants is not an *imposed yield* but a *crop proposal*. He comes to emphasize the need for placing more stress on silviculture and less on the regulation mathematics—a policy essentially sound if not carried to extremes. There must always be leeway in applying a prescribed figure—silviculture must not be throttled—but this is no excuse for prescribing, systematizing and regulating the cut.

78. To Attain Regulation Compromises are Necessary. There is a conflict between the objects of regulation which entail a compromise. The complete attainment of a single goal (such as a sustained annual or periodic cut) may be sacrificed so as to attain partial progress toward age-class distribution, or cutting stands when they are ripe. In another case it may be wise to cut before or after maturity so as to have a more regular immediate annual cut for a local sawmill or to insure better age class distribution of the next rotation. In still another instance more or less than the increment may be cut to attain normal stocking or to allow the development of young stands or prevent the decay of over-mature timber. A point in theory to remember is that under no circumstances would the annual cut be equal to the mean annual increment unless the normal forest had been attained—difficult to attain even under intensive European conditions.

79. Relation Between Increment and Growing Stock. The principle determining the relation between increment and growing stock is normally as follows: one-half the increment will be upon trees cut *within* the rotation, one-half on the *new* crop not yet started. At the *end* of the rotation the timber *now* standing, including seedlings, will have been cut and the growing stock will consist of entirely new stands.

For accurate *regulation* accurate estimates are needed. But these estimates precede the *demand*, and seldom can be *complete* for entire forests but only for small areas where sales are a possibility can be estimated accurately and intensively. On the other hand, no real regulation is possible till the whole group has been *fully* covered by *some* form of estimate. It is for this reason that rapid, cheap and approximate timber surveys are fully justified and are not accessible for sales for many years to come. But the resulting regulation cannot pretend to be very accurate in detail, nor is this accuracy necessary as long as the cut is fairly conservative. In fact it would be faulty management to pay for intensive timber surveys when it was a certainty that the stand could not be cut over for many years. Until there is a method

nsportation to it regulation must be preliminary in character. Thus always a creative period when approximate methods are sufficiently for obtaining increment and growing stock. Yet Moore* is exactly when he says:

rough understanding of the silvicultural requirements of the different trees and methods of cutting which will result in a maximum production of the most valuable is the first essential. In the long run it is generally far better to have over- under proper silvicultural methods than to have a perfect regulation of the cut or methods of silviculture."

must choose between two evils, sound silviculture must not be slighted; it does not justify devastation.

Definitions and Classification of Methods of Regulating the Cut. General classification of methods of regulating the cut may be recognized:

Normal stock or formula methods, when the amount of cut is determined in comparison of actual with normal conditions and the cut is in part regulated by a volume formula for a rotation or equalization period.

Allotment methods, when a rotation is fixed and for a given year or period of rotation a certain area, a certain amount of stock, a certain number or size of trees is allotted to be cut.

Individual or stand methods, when each stand is investigated for its age and designated for cutting, provided other age classes are in existence to insure continuity of crops. (This is usually supplemented by area and volume check.)

An attempt has been made to merge the allotment principle (namely of designating stands for cutting in a definite period) with the various methods to make use of the allotting of stands directly or indirectly.

Table at table II shows the classification of regulation methods adopted in this volume as contrasted with Recknagel, Roth, and Schlich. The writer has tried to select one typical form method for each different class of regulation. The methods have been given first because they have first been used in the United States with irregular virgin stands. In this volume the methods have been arranged as follows:

Volume basis. (1) Growing stock, (2) Increment, (3) Increment and growing stock, (4) Size classes, and (5) Tree as unit.

Area basis. (1) Pure area, (2) Area (and age) allotment by periods.

Area-volume (and age) basis. (1) Volume and area—volume allotment by periods, (2) Americanized stand selection, and (3) Cutting cycle and milling reserve.

Moore, B., *Methods for Regulating the Cut on National Forests* (P. S. A. F. Vol. 12, p. 11).

TABLE II. Relative Classification of Methods for Regulating the Cut used by II Writers.

Schlich (p. 3111, vol. III, 3d Ed.).	Roth (p. 139-159 also p. VII).	Recknagel (p. VIII, also p. 67-126).	Woolsey in this
I. Stand Selection (Judeich).	A. Area methods.	A. Area.	A. Volume Basis
II. A. Fixed Annual Coupes.	1. Fixed yearly cut.	B. Volume.	1. Growing
B. Allotment by Periods	2. Area allotment.	I. Growing Stock Basis.	2. Increment
1. Area.	3. Limited area allotment (Judeich).	1. Von Mantel.	3. Increment
2. Volume.	B. Volume Methods.	2. Masson.	Growing
3. Area and Volume.	1. Volume allotment.	II. Increment.	4. Size Class
C. Increment and Growing Stock.	2. Growing stock.	1. Current Annual Increment.	Periods).
1. Austrian.	a. Austrian (and Heyer).	III. Growing Stock and Increment.	5. Tree as U
2. Hundeshagen.	b. Hundeshagen (and Von Mantel modification).	1. Austrian.	Increase i
3. Von Mantel.	c. Combined methods (see p. 158).	2. Karl.	B. Area Basis
4. Brandis.	d. Diameter limit.	3. Hundeshagen.	1. Pure Area
D. Increment and Growing Stock Combined with Allotment of Areas to Periods (Heyer).		4. Breymann.	
		5. Heyer.	
		IV. Diameter Classes.	
		1. French method of 1883.	
		2. Indian method.	
		3. Diameter class method (Hufnagle).	
		C. By Area and Volume.	
		I. For Entire Forest.	
		1. Gurnaud.	
		II. Based on Age Classes.	
		1. Direct method.	
		2. Hufnagl.	
		3. Stand Method (Judeich).	
		III. Periods.	
		1. Area.	
		2. Volume.	
		3. Area and volume.	
		4. American method (Chapman).	

The following methods of regulating the cut cited by Recknagel (symbols have been used) have not been described in this volume for reasons given:

TABLE 12. List of Formulae Omitted from Text.

Name of method	Page*	Scheme or Basis.	Why discarded.
Masson's method	74	Same basis as Von Mantel.	Duplication.
Swiss method**	74	Divide volume of oldest size classes by c. a. i. of entire stand to get number of years volume of class must last.	Faulty regulation unless normal. Scientific only.
Austrian formula "Kameraltaxe"	78	$\text{Cut} = i + \frac{ga - gn}{r}$ where $i = \text{actual m. a. i.}$	Because r is rigid; it is to distribute surplus cut according to local conditions.
Hundeshagen's	85	$\text{Cut} = \frac{y}{v} = \frac{ny}{nv}, \text{ or } y = v \frac{ny}{nv}$	Identical to Von Mantel's "Austrian," if of distribution $= \frac{1}{2}$

's	86	$y = ny \frac{a}{na}$ (here $a = \text{age}$).	Because surplus or deficit distributed over whole rotation.
	88	$y = \frac{n + ix - nv}{x}$ where $i = \text{a. m. a. i.}$ $x = x \text{ years or period of distribution.}$	See paragraph 85.
class method (agl)	100	Cut = vol. of trees or of diameter classes $\frac{r}{2}$ years + over-plus increment thereof in $\frac{r}{4}$ years; this sum divided by $\frac{r}{2}$ equals the cut.	A rigid scheme rather than a distinct method of regulation. If volume of upper classes very deficient, there might be no cutting.
method (agl)	108	(Average volume per acre = volume of oldest stands divided by area occupied by stand) $\times$ allowed area to be cut = volume to be cut.	Too rigid and no basic method of regulation. If data it requires is available, modified allotment method feasible and preferable.
s method	110	Yield = $\frac{\text{volume} + \text{area} \times \text{increment}^{***}}{2} \times \frac{\text{rotation}}{4}$	See above.

ecknagel's "Theory and Practice of Working Plans."

H. Guise, in J. of F., 1917, pp. 564-573 on "The Swiss Method of Regulating in Practice" advocates a further trial of the method and states it gives a higher does the Von Mantel formula in the case cited.

an annual increment gives a cut 10-20% less than if current increment used.

CHAPTER VIII

(A) VOLUME METHODS OF REGULATION

81. General Principles and Classification of Volume Methods.* For methods should rarely be relied upon as the sole basis for establishing a cut; they should be used as a rough check against other methods that take into consideration volume and area as well as age. The use of a volume check may be necessary in order to answer a problem in yield which does not justify the use of more intensive methods. Under American conditions the use of the board foot unit of measure is a dangerous complication in the use of volume because young stands may yield no board feet; the aggregate of trees have a considerable cubic content per acre. The volume from such stands yield cordwood but no lumber. Therefore the use of an area check when using formulae methods is all the more essential.

Care has been taken to recommend certain formulae methods for use under specified conditions as differentiated from methods of mere scientific interest which nevertheless are explained for the information of the student.

Regulation on the basis of *volume* has been classified as follows:

Main Basis	Secondary Basis	Formulae
(A) Volume.	(1) Growing stock.	(a) Von Mantel
	(2) Increment.	(a) Gurnaud.
	(3) Increment and growing stock.	(a) Austrian. (several forms of A. formulae described.)
	(4) Size classes (and periods).	(a) French method, 1883.
	(5) Tree as unit.	(a) Indian sing method. (b) Diameter limit

Intermediate yield. Whatever method of calculating the cut is employed, the regulation of the intermediate cut from thinnings, clearings, weeding, should be based upon the principle of cutting approximately equal amounts annually or periodically. It is most essential to keep the young stand from becoming too dense and to eliminate undesirable trees as well as the less promising species; then if intermediate cuttings be limited by volume, it might occur that areas in need of thinnings could not be reached. Such areas must be cut over systematically and this can be best insured by covering a certain area each year even if the volume cut is slightly exceeded.

* Methods noted as "of scientific interest" might have been termed "of academic interest."

from intermediate cuttings is usually estimated so as to secure a tentative figure for the annual or periodic budget.

The treatment of the various formulae the method has been (1) defined, discussed and the advantages and disadvantages summarized, and then illustrated by practical examples. Methods noted as "of scientific interest" will not generally be used in the United States.

(1) **Volume Regulation Based on Growing Stock.** a. Von Mantel's* (chiefly of historical interest but often recommended during the stage of organization) is as follows:

$$\text{Annual cut} = \frac{\text{actual growing stock}}{\frac{1}{2} \text{ rotation}}, \text{ i.e., annual cut} = \frac{Ga}{\frac{1}{2} r}$$

$$\text{where } r' \text{ is used, this becomes: annual cut} = \frac{Ga}{\frac{1}{2} r'}$$

$$\text{Basis: on theory } Gn = \frac{r \times i}{2} \text{ or } Gn = \frac{r' \times i}{2}$$

is distributed over $\frac{r'}{2}$ years." It gives the same results as Hundes-

when he finds Gn by the $\frac{r \times i}{2}$ method.

Moore** points out, if r' is used "the yield will be the same as that in the Austrian formula in which Gn is found by the use of r' and the is distributed over $\frac{r}{2}$ years." But the Wolff formula is preferable to's although the basic ideas are similar (see § 66-67).

Assumption. Since this method does not require a study of increment, it is then widely used by the Forest Service in its rough preliminary regulation. The volume to be cut is the keynote instead of the area reproduced age of the stand.

This formula is faulty in that it assumes *normality* but is always applied to actual forest which cannot fail to be *abnormal*. By this assumption it presumes that an amount equal to the present growing stock, surplus or included be cut in half the rotation. The condition of the forest after the time will depend on the amount of increment laid on,

On stands previous to cutting

On stands originating after cutting

On young stands becoming of estimable size after the calculations are

ward*** suggests a modification of Von Mantel's formula to $\frac{Ga}{\frac{3}{8} r}$ for use

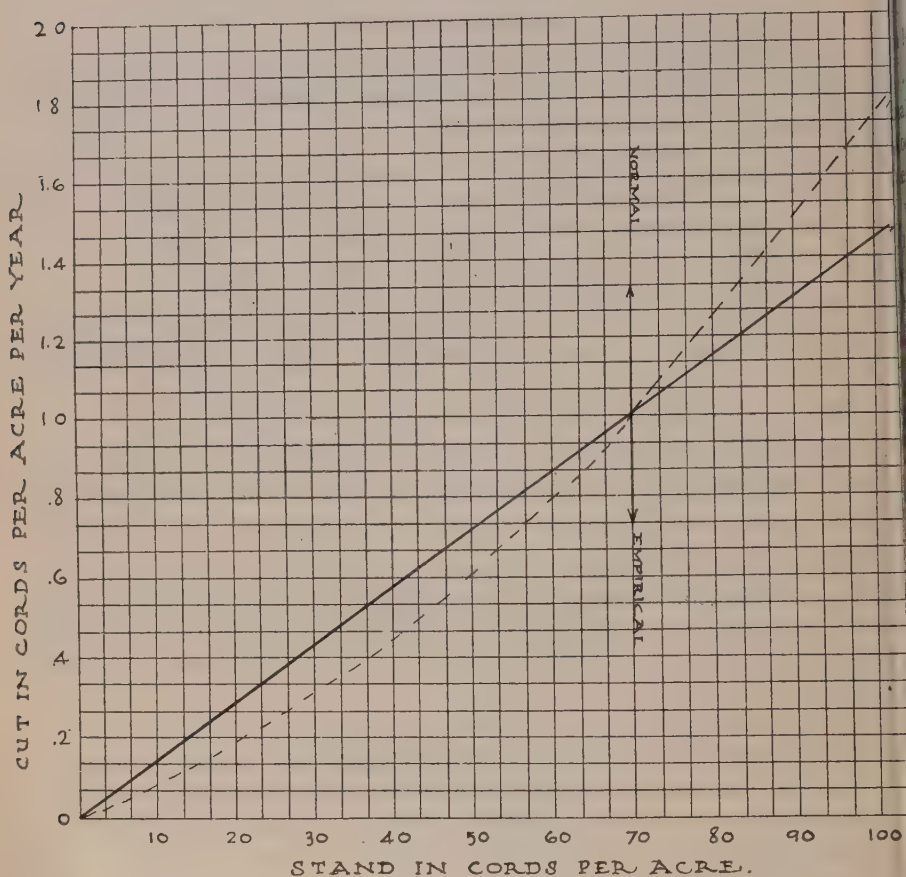
Lesson's (France) formula is identical only it is written $\frac{2Ga}{r}$ instead of $\frac{Ga}{\frac{1}{2} r}$.

aid. It should be remembered that about twice the normal growing stock is probably a forest during the rotation; therefore the amount that can be cut is 2 Gn .

[. of F., Vol. 46, pp. 417-421, August 1, 1920. Von Mantel's formula, or modification of it, should primarily be used as a check against other methods as has been explained in the text. The disadvantages in using this formula, or any other formula, may be diminished if there are very frequent recalculations of yield based on a re-estimate of growing stock. The main difficulty is that frequent estimates, even under intensive conditions in Europe, are a burden of expense.

in Indian selection forests. This has the same disadvantages as Von M... but might be a useful idea under certain conditions.

It follows that over-stocked forests of over-mature timber will be ss...



———— CUT ACCORDING TO VON MANTEL (UNCORRECTED)

----- CUT WITH CORRECTION FACTOR APPLIED (APPROXIM)

FIG. 5. Illustration of the Result of Using a Correction Factor for Von M... Formula.

of all merchantable timber in half the rotation; this would probably waste but might be a serious overcut where the cut was in board feet remaining stand might be too small for merchantable sawlogs. For re-estimating and re-calculation of the cut would lessen these dangers.

The formula error of exaggerating the cut for an impoverished forest cutting too little on one that is rich in material can be modified by cor...

The *per cent* of the growing stock to be cut, Schaeffer says,* should *rather* with 60 cords per acre than with but 20.

enable an impoverished forest to restock less than the amount indicated by the formula should be cut; the *per cent* cut should be reduced."

correction factor is systematized by considering that the *per cent* by the formula ($\text{cut} = \frac{Ga}{\frac{r}{2}}$) is approximately correct for an empirically

stand. Then a table is constructed diminishing the formula *per cent* stands that are 50 cubic metres less than normal and increasing the *per cent* 0.1 for each 50 cubic metres above normal. A correction factor was worked out for 5 soil qualities corresponding to rotations of 120, 140, 160, 180, and 200 years for silver fir. The idea can be applied in the United States, where this formula is used. For a second quality silver fir stand (a rotation of 140 years) the *actual volume* to cut by the formula (corrected and uncorrected) is illustrated by figure 5.

where r' (after Wolff) is used instead of r , this means that the merchantable timber will be cut even more rapidly.

Advantages:

It is inelastic because the surplus or deficit is always taken up in the rotation; if the cut can be frequently re-calculated upon the basis of new estimates this objection is less serious.

With board feet it gives too low** a cut unless r' is used.

It rests on *faulty regulation* because it neglects the age and rate of growth of stands and area of cuttings (an area check corrects this to a certain extent).

Only of use in preliminary and crude regulation (even then should be used only *with* area check).

It has not been thoroughly tried out by experience*** (abandoned in France).

Advantages:

".....Will gradually lead to the establishment* of the normal growing stock" and ".....adapts the cut to the actual growing stock on hand....."

It is easy to apply since it merely requires the actual growing stock on hand; it is handy.

Of value in preliminary and crude regulation where an approximate area check is required by law (as on National forests).

Illustration. Given: Case (1) $Ga = 1,043,000$ board feet.

Case (2) $Ga = 1,304,000$ board feet. (This coincides with G_n .)

Case (3) $Ga = 1,565,000$ board feet.

Schaeffer, A., Un Correctif à la Méthode Masson, Bulletin de la Société forestière de l'Aube—Compte at Belfort, No. 3, 1905.

ibid., p. 18.

Roth, Filibert, Forest Regulation, p. 157.

Weylich, Vol. III, p. 320.

Where $r = 60$, $r' = 45$ years and the area 60 acres.

Then by cut = $\frac{Ga}{\frac{1}{2}r}$	Case (1)	$\frac{1,043,000}{30}$	= 34,766.
	Case (2)	$\frac{1,304,000}{30}$	= 43,466.
	Case (3)	$\frac{1,565,000}{30}$	= 52,166.

Reference is made to a comparison with the Austrian formula § 85; see also 83. (2) **Volume Regulation Based on Increment Alone.** Since all forest abnormal (see Chapter VI), the use of increment alone for purposes of regulation considered dangerous and inadvisable especially under American conditions.

The idea expressed in the Gurnaude* plan is little more than of scientific in Gurnaude simply treated the forest as a sample plot and increased or decreased according to the results of past cutting modified by the dictates of current silviculture and market conditions. If the forest was about normal (on an empirical basis) annual cut was supposed to equal,

$$\frac{(\text{Present } Ga - \text{former } Ga) + (\text{cut between stock takings})}{(\text{Years between measurements})}$$

In applying the allowed yield they endeavored to cut according to the empirical representation of age classes in the ideal selection stand for the species in question.

This is of course faulty in that it presumes (unless applied with great judgment) that growth should be the cut—a mistaken ideal. It also necessitates frequent re-measurement, a factor which is exceedingly costly in the United States.

Furthermore the Gurnaude* idea really goes further and seems to subordinate modern conceptions of a fixed rotation, of a sustained or fixed yield, or of a normal forest to a flexible method of silviculture that will give the owner the *greatest possible growth*. The forest is to be intensively managed as a number of sample plots with frequent stock taking (every 5 or 10 years). The cut is to be based on the results obtained over short periods rather than on predictions for several decades. The sustained yield and the ideal normal forest will be secured, Biolley claims, by carrying out the aim of getting the largest possible growth with the minimum possible growth stock. The method aims at largely subordinating forest regulation to silviculture, a method it would rarely be applicable in the United States even under intensive conditions; moreover, the method is really an *idea or policy rather than a recognized and distinct system of regulation*. It is an idea that could be applied with any regulation method and as a matter of fact, is made use of by the best management men in France, applying the French method of 1883. In fixing the yield the regulator studies the volume, age classes, and growth on each lot.

Disadvantages: (1) If current increment is taken as the basis of the cut, it will be too small with decadent forests and too great with immature stands.

(2) If mean increment is taken (if *actual* mean is taken for each age class, the result is much too high for young stands and too low for overmature stands) overmature stands will not be reduced, nor immature built up by merely cutting the increment because the present amount and age of timber is not considered.

(3) It is expensive and difficult to measure the increment on the entire forest.

* Those who wish to study Gurnaude's ideas on regulation should refer to La Méthode du Contrôle, P. Jacquin, Besançon, 1886, pp. 1-124; also La Méthode du Contrôle, exposition universelle de 1889 published in 1890. See Recknagel (*ibid.*) p. 106 and 74-77; also Studies in French Forestry by T. S. Woolsey, Jr., John Wiley & Sons, pp. 206 to 243.

** Recknagel, A. B., Forest Working Plans, described (pp. 74-77) as the "Sustained Yield" method regulation by increment alone, but the writer prefers not to introduce it to American forest students.

* Biolley already cited, p. 29 and 59.

To be at all satisfactory there must be a normal age class distribution which is normal.

antages: None; but often of interest and value as a rule of thumb check on actual increment under the practical conditions that have prevailed in the forest. Losses from suppression, etc. are shown in the calculation.

(3) **Volume Regulation Based on Growing Stock and Increment.** The stumbling blocks to this class of formula are: (1) How to calculate the actual growing stock; (2) whether to use current or mean annual increment; should this be the normal or actual increment?; (3) the term of years for which the surplus or deficit should be distributed.*

The best results in regulation based on growing stock and increment are obtained by the following methods:

Calculate the normal growing stock by the yield table method (see § 66-69) where practicable; if not, use $\frac{r \times i}{2}$ or where board feet are used, substitute $\frac{i(r^2 - s^2)}{2r}$ (see § 66-67).

Use actual mean annual increment instead of the current annual. Actual increment should not be used.

The surplus or deficit should be distributed according to the conditions of the stand and according to the economic possibilities for saving. Usually, if ever, will the entire rotation* be used as the time within which to distribute a surplus or deficit.

The distinctions between the various formulae based on growing stock and increment are illustrated in the table which follows.

TABLE 13. Distinctions Between Formulae Based on Growing Stock and Increment.

Name of Method	Historical Reference	Formulae	Remarks
Austrian (as modified by Guttenberg or German).	Roth, p. 150 Schlich, p. 314 Recknagel, p. 78	Cut = actual M. An. $i + \frac{Ga - Gn}{x}$ (Most practical adaptation).	Actual mean annual increment is used and it is assumed x is flexible rather than the rotation time.
* Roth	Schlich (not given) Recknagel, p. 83	(Of scientific interest.) Cut = actual current An. $i + \frac{Ga - Gn}{x}$	Actual current annual is used. Not described by Roth and Schlich.
Swedish** Von Sjostedt, p. 75)	Roth, p. 56 Schlich, 317 Recknagel, p. 85	(Of scientific interest.) Cut = $Ga \times \frac{ni}{Gn}$	Avoids the calculation of actual increment. Is inelastic. Basis incorrect.

Roth, Filibert, Forest Regulation, p. 151 holds, as does Von Guttenberg, that it is an error to consider the Austrian formula as spreading the surplus or deficit over an entire rotation. See also Indian Forester, March 1922, pp. 122, 126.

Those who are interested in the variations between these formulae are referred to § 91 of Forest Working Plans by A. B. Recknagel, but it should be borne in mind that the variations will change according to the period of distributing the surplus or deficit and according to the data assumed as a basis for the example.

Breymann's**	Roth Schlich (not given) Recknagel, p. 86	(Of scientific interest.) Cut = $M. An. i \times$	Normal age = half the rotation. Has the dis- taste of being inelas-
		$\frac{\text{Normal Age}}{\text{Actual Age}}$	
Heyer's** (see par. 85).	Roth, p. 154 Schlich, 325 Recknagel, p. 89	Cut = $\frac{Ga + i - Gn}{x}$	i is the actual M. an. ment for rotation.
		Roth does not distinguish the Heyer formula from the Austrian.	See discussion of Au- strian method where x is variable.

Of these formulae Heyer's is the most accurate in theory, but since formula methods are approximate, a simpler form is preferred.

To give satisfactory results the formula must be based on actual annual increment and the surplus never rigidly distributed over the rotation. An analysis of the formulae shows that Karl's can be discarded because it is based on actual current annual increment and possesses advantages secured by the flexible type of the Austrian formula. Huthagen's is too inflexible because there is no choice as to decreasing or lessening the time for the distribution of surplus or deficit. Breymann's presents too intricate a problem when it comes to determining the actual average. Heyer's embodies the same principles as the modified Austrian but with improvement. Therefore but one type of formula is described and illustrated.

85. (a) The Modified Austrian Formula. (Von Guttenberg form; termed Heyer modification). The formula reads:

$$\begin{aligned} \text{Annual cut} &= \text{actual mean annual growth} + \\ &\quad \text{actual growing stock} - \text{normal growing stock} \\ &\quad \div \text{years over which cut is distributed} \\ \text{i.e., annual cut} &= \frac{\text{m. a. i.} + Ga - Gn}{X} \end{aligned}$$

Discussion. The increment used is ordinarily the actual mean annual increment. The actual growing stock must be obtained by an inventory of the forest. The normal growing stock is computed preferably from yield tables

or from the formulae $\frac{r \times i}{2}$ or $\frac{r' \times i}{2}$ (see § 67 to 68). The surplus or deficit

distributed in a shorter or longer period according to the dictates of good silviculture and good business. If the timber were very over-mature, the tendency would be to reduce the surplus rapidly. If a deficit existed, it should not be made up so quickly that the resulting forest would contain diseased timber. Nor could economy be practiced to such a degree that the yield for local dependent industries would be dangerously reduced. Where the actual stock (as in the West) consists largely of mature and overmature timber, the apparent surplus over the theoretical normal stock is not potentially as great as it may appear to be. For when all the over-ripe timber is cut for silvical reasons there is likely to be a deficit in growing stock because there is no middle-aged timber.

The Austrian formula gives the same results as Von Mantel's (see § 84) if the period of distribution (or equalization) is taken at $\frac{1}{2} r$.² With lo-

shorter periods of distribution the cut by the Austrian formula will be greater than that by Von Mantel's.*

Before using the Austrian formula it is well to bear in mind its peculiarities,

Application to a given volume in the forest. The smaller the mean annual increment on this volume, the more overmature the forest and the smaller the annual cut because the normal stock depends on increment; the smaller the cut due to the surplus more than offsets the loss due to the small increment. The result of cutting is a large reduction in the surplus. Hence the normal current increment in old stands were used, heavy cutting is indicated and is obviously good forestry. Conversely, the larger the increment, the smaller the cut, until the forest becomes normal, because a large normal increment is indicated.

With a long rotation the cut is diminished because of the increase in normal stock. Therefore a conservative cutting of the present forest is secured by adapting as long a rotation as possible.

With a longer period for the distribution of the surplus the cut is of course diminished; again, if there is a surplus in the growing stock, then the cut can be increased by a short period of distribution.

Conservative cut demands the use of the actual mean annual increment at culmination as the basis for the normal stock. For a rapid cut use the current increment (especially in old stands), with a short rotation and a short period for distributing the surplus.

Advantages:

It is highly artificial and tricky, especially with a board foot measure, as the normal stock is calculated by the formula $\frac{i(n^2 - s^2)}{2r}$ (see § 66-67) from yield tables; even then it is subject to error.

It assumes that i and G_n remain constant whereas they are continuously changing because of natural and artificial causes. This is not as serious a defect as might appear because it is corrected at the time of revision.

It ignores area and age. It is an "office" rather than a "field" method of regulation.

Advantages:

It is elastic because there is wide choice as to the number of years which to distribute the surplus or deficit.

The objective of always trying to approach the normal stock is clearly the regulator.

Adapted to extensive forestry and clearly distinguishes between capital and income, but its value lies chiefly in its use as a check on other methods.

For example given $i=100$, $r=100$, $G_a=7,000$, $G_n=\frac{100 \times 100}{2}=5,000$ and if 50 years, the Austrian formula works out $50 \times 100 + \frac{7,000 - 5,000}{50} = 140$, while by Von Mantel we have $\frac{7,000}{50} = 140$, an identical figure. The Austrian and Von Mantel give the same results only in case the inaccurate $\frac{r \times i}{2}$ formula is used to calculate the normal stock.

Illustrations. Given for a forest of 60 acres:

	Case (1)	Case (2)	Case (3)
Ga	1,043,000	1,304,000	1,565,000
Gn	1,304,000	1,304,000	1,304,000
m. a. i	1,003	1,003	1,003
r	60	60	60
x	50	30	15

It follows that:

$$\text{Case (1), Cut} = 60,180 + \frac{1,043,000 - 1,304,000}{50} = 54,960$$

$$\text{Case (2), Cut} = 60,180 + \frac{1,304,000 - 1,304,000}{30} = 60,180$$

$$\text{Case (3), Cut} = 60,180 + \frac{1,565,000 - 1,304,000}{15} = 77,580$$

In case (1) there was a deficit of growing stock, so the cut was reduced; (2) there was no change because the growing stock was normal; in case (3) there was an excess growing stock, so the allowed cut was largely increased and especially the excess was to be cut in 15 years.

86. (4) **Volume Regulation Based (on Growing Stock and) Size Class (and Periods).** (a) This so-called method* of 1883 as applied to selection forests of tolerant species is as follows: After inventory (by diameter class) determine the rotation and the corresponding size of tree, then classify the growing stock in three classes: (1) *Old wood*, trees more than two-thirds the allowable (rotation) size; (2) *Average wood*, trees less than two-thirds and more than one-third; (3) *Young wood*, less than one-third (usually not calipers). Where there is a normal (or nearly normal) proportion of old and average wood (see discussion), the cut** equals the volume of the old wood divided by age of the rotation plus half the annual growth on the old wood class while being cut.

87. **Discussion of French Method of 1883.** The method was designed for selection high forests of tolerant species, where the regeneration could be secured in at least one-third the rotation, and where a sustained yield was important. It is based on the conception that a selection forest, normally constituted, is just like an even-aged forest (where, on equal areas, specimens of all ages up to the rotation age are found), except that the various size trees are intermingled. In the latter case an equal cut is secured by cutting

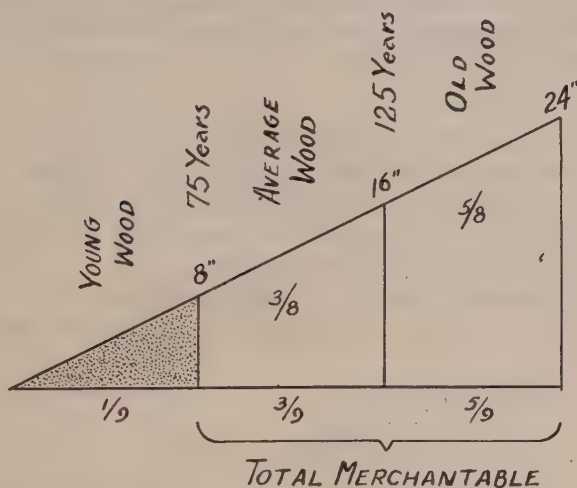
* Based on the original official instructions issued by the French Secretary of Agriculture and on the Chamonix Working Plan by A. S. Schaeffer.

** Compare this method with the Hufnagel "diameter class method" described by Hufnagel (ibid.), pp. 100-105; The Hufnagel method (Variation 1) is: Annual cut = volume of trees or of diameter classes $\frac{r}{2}$ years and over, plus increment thereof in $\frac{r}{4}$ years.

Recknagel gives an interesting example of (Variation 2) where the trees have been grouped by 3-inch classes with the basis data (for each class) of volume per acre, average number of trees per acre, and years required to grow from one class to the next (and "average age of the average tree in each diameter class). For each class the annual increment equal to volume of class $\times$ number of trees per acre. The yield for all classes can be increased or decreased according to the surplus or deficit in the growing stock. According to Recknagel's example the surplus is reduced in one cutting cycle, and the deficit is made equal to the number of years to grow to the highest diameter class from the preceding class. For more complete discussion see Recknagel.

near areas of the same size and productivity. But in the selection forest cutting must remove only ripe trees here and there over the entire area at any comparison of *surface*. Therefore, in this case *volume* must be tuted for surface.

The method is based on the assumption (see diagram) that the volume of old wood is $\frac{5}{8}$ and the volume of the average wood $\frac{3}{8}$ the total *merchant-volume*, it being presumed that the young wood is unmerchantable.



According to the French Secretary of Agriculture, the data furnished by research on the mean annual rate of growth of high forests shows that this relationship is approximately as 5 is to 3. Therefore whenever in a selection forest the volume of the old wood and the average wood is as 5 is to 3, it may be taken for granted that these two groups are similar to the first two periodic blocks of a high forest. To demonstrate that the volume covering the first two periodic blocks of a regular high forest (divided into three periodic blocks) are about as 5 is to 3, which represents their average age respectively, it suffices to note that the trees of the second periodic block are average wood, which has arrived at a state where the annual growth is uniform and just about equal to the average of the stand and at a period where it is safe to figure the future growth as equal to the past average. If a high forest with a 150-year rotation were divided into three periods of 50 years each. The average age of the first (old wood) and second (average wood) periodic blocks will be 125 and 75 years and will be separated by a length of time equal to a period of 50 years. In admitting that the future growth will be equal to the average growth, the volume of the 125-year old wood will be equal to that of the 75-year old wood *increased* by an amount

equal to 50 times the annual growth. Then if we designate the volume of the 75-year old wood as 3, the 125-year old volume will be $3 + \frac{3}{75} \times 50 = 3 + 2$, or 5. This assumption of an equal mean annual growth, of course, is not exact, but according to French reasoning it is sufficiently accurate for an *approximate formula*, which is being continually revised at working revisions, when the standing timber is re-calipered.

"One can object to this method of classification because the diameters are not exactly proportional to the ages, that they are not equal for the same species, or same conditions. But it is to be supposed that with a large number of trees . . . an adequate compensation will take place in order to even off the inaccuracies and render them negligible. Moreover it is not essential to arrive at exact mathematical results (if possible)."

The language and argument of the original French instructions is instructive in considering the method and in applying it. As originally promulgated so as to be conservative, no increase was made in the cut for the growth which took place on the old wood while it was being harvested. But within recent years it is customary to figure growth.

The method is simple when the proportion of the old wood to the young wood is as 5 is to 3, or *nearly so*, but this normal ratio is not usually found. Instead there is,

- (1) An excess of old wood, or
- (2) An excess of average wood.

In either case (1) or (2) an approximately normal ratio is secured by transferring diameter classes from the old wood to the average wood or vice versa, if it is safe silviculturally to hold over some of the older trees or if (when the average wood is too great) the large average wood sizes can be cut without too great a sacrifice.

An important feature of the *application* of this method by the best French working plan officers is that they compare the actual growing stock (on the basis of number of trees per acre of different sizes) with an empirical "normal stand (an adjusted average for the region). This is an essential and important part of the method *as best applied* but is not mentioned in the official instructions.

If desired, a rough area check can be applied by considering that the cut over should be proportional to the volume removed. The original instructions stipulated that (1) the length of the cutting period be a submultiple, a third of the rotation, (2) the number of compartments be about equal to the years in the period, (3) the local forester be free to allot the amount of the cut in each compartment according to local requirements at the time of cutting, and (4) the yield be revised at the end of each felling period.

Disadvantages:

- (1) Unless there is some other check on the normality of the old wood and average wood besides the proportion of 5 to 3, it is insufficient because an acre might contain 5 board feet of old wood and 3 board feet of average wood.

800 M) will be deducted from the old wood. Thus $6,200 \text{ M} - 800 \text{ M} = \frac{5,400}{60}$, equal (plus growth).

C. Suppose the volume of the old wood = 3,300 M and
the volume of the average wood = 4,700 M.

Here the average wood is in excess of the normal ratio so it is determined whether or more of the largest average wood diameter classes can be transferred to the wood for immediate cutting. If it is found that the 16-inch diameter class (which will presume totals 600 M) can be added to the old wood, the volume will be 3,900 plus 600 M, which equals 4,500 M, and the cut, $\frac{3,900}{60}$, equals 65 M (plus growth).

89. (5) **Volume Regulation Based on the Tree as a Unit; (a) The Single Tree Method (Brandis*).** (Of scientific interest, but might be in the Philippines.)

The forest is first inventoried by broad diameter (in India = girth) class. Then the current rate of diameter growth determined, a technical rotation established, the mortality loss estimated, and finally the average number of trees mature annually computed (by multiplying the trees in each class by the percentage which will survive) and the cut fixed so as to remove the surplus stock (or supply deficiency) within a reasonable period. (See illustration.)

Discussion. The method originated in Burmese teak forests where merchantable timber comprised but one tenth the stand. According to Schlich,

"... Brandis's object was to ascertain as quickly as possible the number of class teak trees which might be removed annually without exposing the forest to deterioration."

It must therefore be clear that the method is approximate and was designed simply to prevent overcutting in a tropical forest where but few species are merchantable. Since it deals with trees rather than a unit of measure, it is simple and easy of application in a country where low class labor must be used in valuation surveys. In recent** years,

"The area check is applied by prescribing the order of the fellings through different subdivisions (compartments) of the working circle. A table is drawn up showing for each year the subdivision on which the cut is to be located and number of trees to be removed."

In the United States there appears to be no justification for the use of this method but it might be of value in the Philippines during the initial stages of forest management.

The *weaknesses* of the so-called Brandis method are as follows:

(1) The growth calculations are based on current growth in diameter and in India particularly, this data is often scanty and unfortunately must be applied for considerable periods.

(2) The mortality per cent is evidently a most essential part of the calculation, and yet according to the authors themselves, the basis for the mortality per cent is a mere guess.

* This is based on Vol. III, Schlich's Manual of Forestry, pp. 321-325. The illustration is adapted directly but with added explanation.

** Moore, Barrington, Methods for Regulating the Cut on National Forests (P. S. 1912, p. 25).

The basis for determining the rotation is the length of time it takes a single tree to grow to a certain size. The factors of the mean annual volume production per acre cannot be weighed—a most unfortunate feature in any yield method.

Particularly where the forest is a mixed stand and where only one species in this stand is merchantable, there is grave question whether the larger age classes will survive a selection cutting which cuts one species which is merchantable and must leave less desirable species in possession of the ground. With this form of cutting the inference is that natural regeneration of the desirable species will be unsatisfactory and therefore any method which counts on the survival of the desirable species now being lumbered is dangerous unless very frequent stock taking can be afforded.

The question of individual judgment is paramount, and different men will calculate a vastly different number of trees to cut. While this criticism is true in a certain measure of almost all yield calculations in their final analysis, and rightly so, yet in other methods the personal judgment is of great weight.

The following might be cited as advantages:

1) It is suited for extensive tropical forests where only one or two species (such as teak) are merchantable and where crude selection felling is the rule.

2) Stock taking by native labor is possible owing to the use of broad diameter or circumference classes.*

3) Adapted for an initial check on cutting, where, because of economy, the more modern methods cannot be applied.

Illustration. The productive forest area is taken as 84,022 acres of 51 compartments. The field work showed:

I Class (D. B. H.) inches.	2 Initial No. of trees (trees available).	3 Total age (years) on entering class.	4 Years to pass through each class.	5 Percentage surviving and entering next class.
I over 28	31,523 (29,947)	156		95
II 24-28	18,114 (15,397)	130	26	85
III 18-24	42,768 (29,938)	93	37	70
IV 12-18	101,737 (50,869)	60	33	50
V 6-12	150,910 (37,728)	31	29	25
Row 6 not counted.				
Totals	345,052 (163,879)	156	156	
Class II-V	(133,932)			

For a further discussion of this method see P. S. A. F., 1912, pp. 24-27 and *Forestry Quarterly*, p. 910, p. 52, and pp. 332-333. In the *Quarterly*, p. 52, Class I should be instead of $\frac{3\frac{1}{2}}{100}$.

These figures are from a Burmese working plan by A. Roger. In the original column 1 was by girth classes. In column 2 the upper figure in each class is the of the original stock taking and the bracketed figure the original stock multiplied the percentage in column 5.

Column 3 is based on the data in column 4 which is the result of stump analysis only 198 trees. Column 5—the crucial and important figures—is based on

“observations made in this and other forests in Burma from which it was ascertained that the following percentages of sound trees are likely to survive and be available for utilization.”

The rotation was 160 years, 5 periods of 32 years each. It is clearly based on the number of years it takes a tree to grow up to the class V following 31 years to up to class I.

90. (b) **Diameter Limit (Pinchot-Graves).** (Of scientific interest.) This method (now abandoned by American foresters) is similar to the single tree method in that it is based on current growth in diameter of single trees but with a volume unit for yield instead of the number of trees. It is of historical interest, only, and was first used in America in “The Adirondack Spruce” by Pinchot. Any method of regulation (unless the forest can be frequently re-estimated) based on current growth of individual trees is of little or doubtful value because of the uncertainty regarding the number of trees which pass from one diameter class to another (i.e., mortality percentage). It was described in France* as early as 1867 and is now only applied to beech selection coppice (*taillis fureté*) chiefly in the Pyrenees. Huffer says that

“such a system can evidently be applied only to forests very nearly normal. (‘normality’ is rarely found.) In a fir stand rich in large trees, seedlings and saplings but poor in average sized trees, it would result in a short period of super-abundance which would be followed by a period of largely reduced fellings or even by a complete suspension of income.”

Such a method is clearly unwise especially for virgin forests in the United States; nor is the Gazin** idea of more than scientific interest.

* Huffer, *Économie Forestière*, Vol. III, page 68. The term “of scientific interest” might be “of academic interest” throughout the text.

** *Stem Space Method (Gazin)* (Of scientific interest). The stem space method of regulation is based on silviculture rather than on any mathematical formula. It is a silvicultural idea rather than a method that can be defined in a few words. Its basic features are:

- (1) Normal spacing of the boles without reference to form of stand.
- (2) To yield the maximum volume with the smallest growing stock by keeping the boles normally spaced.
- (3) *The idea of rotation is done away with.*
- (4) The details are worked out on an average acre (normal in an empirical sense) and the treatment of the actual forest is hand patterned after it.

The method (too intensive for present conditions in the United States) is of scientific interest because of the ideas it introduces, but it is of doubtful practicability and it has been successfully tried out and applied. Its advantages or disadvantages cannot be appraised as yet. (From Gazin, A., *Le Traitement des Sapinières basé sur la notion d'espacement des tiges*, Paris, Imprimerie Lahure, 1902, pp. 1-17. The metric system is used. Translation of this article may be studied in the 1917 *Journal of Forest Management*. See also § 83.

Quiz. Define regulation of cut.

What are three aims of regulating the cut?

Explain why compromises are necessary.

Explain the classification of methods of regulating the cut.

What are the three main bases?

Explain the main differences in regulating the forest on the main basis of (a) volume, (b) area, and (c) area-volume (see Chapter IX).

Explain four bases of subdividing regulation on the basis of volume.

What is the Von Mantel formula? its faults? its advantages?

What is the Gurnaud idea?

What is a method of regulation?

What is the basis of the Austrian formula? Explain it.

Explain some peculiarities of the Austrian formula. Its advantages and disadvantages.

Explain the French method of 1883.

From what was the formula derived?

Illustrate its application to a selection forest.

Is it customary to figure growth on the "old wood" while it is being cut? Why?

What are the advantages and disadvantages of the method of 1883?

Why is the Brandis single tree method unsuitable for the United States?

What is the fundamental error in the Pinchot-Graves diameter limit scheme?

Why is the Gazin scheme of no practical value?

CHAPTER IX

(B) AREA, AND (C) AREA-VOLUME METHODS OF REGULATION

92. (B) **Value and Classification of Area Methods.** Proper regulation must take into consideration the volume, age, and area of a stand. Volume alone, as exemplified by the various formulae methods already described, is insufficient. Regulation by *pure* area alone is lacking in flexibility and does not consider sufficiently the essential factors of volume and changes of volume necessitated by acts of Providence (such as windfall or disease).

The inclusion of area allotment by periods under regulation by area tends to simplify the classification but is a departure from German procedure. Regulation on the basis of area (and age) has been classified as follows:

Main basis, *

(B) Area (and age).

Secondary basis,

(1) Pure area.

(2) Area allotment by periods.

93. (1) **Fixed Area as a Basis for Regulation of Cut.** The simplest conception of pure area regulation is, *the forest is divided into a number of cutting areas equal to the years in the rotation and one area is cut each year.* Two modifications of this basic plan may be necessary: (a) If the soil quality of the forest varies, then a proportionately larger area of the poorer sites must be laid out on the ground. (b) If the forest is so small that yearly logging is not justified, then the cutting areas are made proportionately larger to provide for cutting every two, three, or more years as the circumstances require.

Discussion. Regulation by fixed area may be of practical value in coppice forests or coppice under standards where regeneration is certain. It may also be used in stands managed on a very short rotation and where the commercial crop is obtained by planting or sowing; a case in point would be the commercial production of Christmas trees. The fundamental idea of working over equal areas each year or periodically is the basis for regulating oak production or resin crops, with the necessary silvical and commercial limitation on what cork is marketed or what trees are tapped for resin.*

The European conception of fixed area regulation is to follow the plan of cutting marked on the ground, but there is no practical reason why a stand nearly ripe but damaged by fire, could not be cut ahead of its maturity. Success must then be made and a corresponding area held past maturity.

Disadvantages:

(1) The method is rigid and with a change in rotation or scheme

* See French Forests and Forestry and Studies in French Forestry, both John Wiley & Sons, for a discussion of cork, oak and resin regulation.

ing, the whole forest must be redivided into entirely different cutting

Forces cutting without considering the condition of the stand.

tages:

Easy to apply.

Equal annual or periodic cut and absolute regularity of age classes.

Illustration of Fixed Area for Limiting the Cut. Given: Coppice forest of 100 half on ridge (site III) and half in a valley (site I); rotation and cutting cycle 20 years; annual cut required for constant fuel supply. Site I yields 20 cords at 20 years and site III only 10 cords.

If the soil value had been equal, the annual cutting areas would be $\frac{100}{20} = 5$ acres; if the half the stand is on a rocky ridge with one-half the soil value of the remainder; the average reduced cutting area must take into consideration that the cut from two acres of the poor soil equals only one acre of the good soil. By a simple calculation $\frac{1}{2} \times \frac{1+50}{20} \times .5 = 3.75$ acres, and $\frac{50}{3.75} = 13$ areas with 1.25 acres of site I left

on site III the cutting area would be double that of site I, i.e., $3.75 \times 2 = 7.50$, $\frac{100}{7.50} = 13.33$ areas (with 5 acres left over), the cutting areas are found to be as follows: on site I, 13 areas of 3.75 acres each; for site III 6 areas of 7.50 acres each. This leaves one area composed of 1.25 acres site I, and 5 acres site III, which would be in producing capacity to 2.50 acres of site I or a total of 3.75 acres (site I). The yield in cords would be obtained by multiplying 3.75 acres (site I) by 20 cords per acre or on site III 7.50 acres $\times 10 = 75$ cords, which is an identical figure.

(2) **Area Allotment by Periods as a Basis for Regulation.*** *An allotment method—when a rotation is fixed and for a given year or period of rotation a certain area is allotted to be cut.*

Discussion. This is somewhat similar to regulation by pure area (with fixed cutting areas) but decidedly less rigid and differs in that the cutting areas are not permanently fixed on the ground in the order of cutting but that compartments or lots are allotted to the various periods of the rotation. These periods are 10 to 30 years in length and the total number depends on the length of the rotation. The stands allotted to the first period are,**

measured, their volume calculated, and the increment for half the number of years of the period added. The total of the volume thus obtained is divided by the number of years in the period to obtain the average of the final annual yield during the period thinnings must be added."

In a matter of fact, in the modern European working plan allotments are recorded for one, or at most two, periods. Since the working plan will be revised at the end of the period, it is unnecessary to make permanent allotments far ahead because changed conditions may force a complete change; it is for this reason Judeich originated his stand selection method (par. 100).

It must be clear that before individual stands (which may be allotted) are cut the growth continues on the uncut growing stock in these stands. After

* See Schlich, Vol. III, 3d Edition, p. 311.

** Ibid, p. 313.

the cutting, regeneration and development of the seedlings goes on, but there is no immediate tangible merchantable increment. If, for example, 20 stands are allotted to a 20-year period, then after the first year 19 stands will be growing while at the beginning of the 20th year only one stand will remain. This explains why in all methods of regulation dealing with individual stands or age classes (as in the French method of 1883) half the growth is added to the estimated yield of the stands to be cut.

To sum up, there is no reason for using *area allotment* when better results can be obtained by taking into consideration volume and "stand selection." Even in Prussia the area allotment was only used for very regular stands.

Disadvantages:

- (1) Age class distribution may be neglected in first rotation.
- (2) Surplus growing stock is not reduced, and immature stands may be sacrificed.

Advantages:

- (1) It is simple and easily applied in the office, and tends to quickly establish the normal distribution of age classes.

Illustration. Since the method is not recommended, no original illustration is given. Those interested in seeing how the method is applied in Europe are referred to pp. 382-387 Schlich, Vol. III, 3d edition. Here it will be noted that after the various stands are allotted to each of the five periods, there is still a considerable variation in the areas to be cut over; namely, in round figures 30, 34, 33, 32, and 30½ acres, the average area of the period being 32.03 acres. The smaller the lots, the more accurate the equalization for each period. The period in the illustration is 20 years, so the areas of the stands listed for cutting are taken not at the beginning of the period but to the middle of the period (i.e., age at beginning of period plus 10 years). The yield is read from the yield table for the species and age and then multiplied by the number of acres; this procedure of taking the yield to the middle of the period obviates making a separate calculation for growth. The estimated yield from thinnings is then added to the yield from the main stand.

96. Use of Yield Tables in Computing Volumes. When using yield tables with a period (or stand) method of regulation, it is often convenient to reduce a yield table which is fully stocked to terms of the stand which is not fully stocked. This is done by comparing the average stand volume per acre with the volume per acre given in the yield table. Before making the comparison, it is of course necessary to obtain the average age of the stand either by sample trees or on the basis of the age of the tree corresponding to its average diameter. For example, suppose the mature age class 200 years old averaged 8,375 feet per acre and the yield table 16,750, then in reducing future empirical yields to apply on the forest all figures in the yield table are reduced one half, because,

$$\frac{\text{stand}}{\text{yield table}} = \frac{8,375}{16,750}, \text{ or } \frac{1}{2}.$$

When long periods are used in calculations, it may be advisable to compute the cut by the weighted yield table formula instead of computing the cut by (a) reading to the middle of the period in the yield table or by (b) read-

the yield table to the first year of the period and then adding half the h. The weighted yield table method merely recognized that the mean growth is a curve and not a straight line and is fully explained in the *Journal of Forestry*.*

(C) **Area-Volume (and Age) Basis of Regulation—Value and Classification.** Volume alone is not a satisfactory basis for regulation, nor is age or area alone, because in the latter case the factor of volume is omitted as a determining factor. It is clear then that the ideal of regulation is to consider *area, volume and age*. Taken together they constitute the essential factors to be considered in regulating a forest, while singly they are simply important, but not determining, factors. As many writers point out, and has been repeatedly emphasized in this book, the old fashioned idea of allotment to all periods of the rotation is generally abandoned. With this modification there is not such a vital difference between (1) and (2) given above. Regulation on the basis of area-volume (and age) has been classified as follows:

Main basis,

Secondary basis,

- | | |
|----------------------------|--|
| (C) Area-volume (and age). | (1) Volume and area-volume (age) allotment by periods. |
| | (2) Stand selection. |
| | (3) Cutting cycles and felling reserve (see part II). |

(1) **Volume and Area-volume (and Age) Allotment as a Basis for Regulation.** The definition is similar to that for area allotments by periods: *In a rotation is fixed and for a given year or period of the rotation a certain amount of stock is allotted to be cut.*

Discussion. The so-called volume allotment method has not been separately discussed because it possesses no advantage over the method of periods by area and volume combined. In volume allotment by periods the chief aim is to equalize the volume rather than the area (see § 95). Volume allotment as practiced in Europe is illustrated by Schlich, Vol. III, 3d Edition, page 100. Volume allotment was the dominant method in Prussia during the 19th century but is now replaced by volume-area allotment with a view to a more equal distribution and felling series. With area-volume allotments the areas and volumes allotted to the first period are divided by the years in the rotation to obtain the area to be cut over and the volume which will be secured in the main fellings. Then the aggregate of individual stands is either increased or diminished according to the areas and volumes (and ages) of the stands which should be felled. The goal is regulation on the basis of the individual compartments, and the smaller the stand (lot), the more equalized the estimate of volume and the more intensive the regulation. Taking into consideration and weighing both area and volume gives somewhat similar results to area allotment but with a very careful check on the site quality of

* Woolsey, T. S., Jr., *Computing Volumes in Period Allotment*. (J. of F., 1917, pp. 34.)

each lot gauged by volume. The choice of the stands to be allotted on maturity (and age), their relation to the felling series, a sustained yield and the regeneration of the most desirable and suitable species.

Disadvantages:

- (1) Equalization and allotment of both area and volume is a difficult task.
- (2) Suitable grouping of age classes is difficult.
- (3) Cuts of equal area and volume are not desirable if stands of mature timber must be held over or young timber sacrificed.
- (4) It possesses no clear cut advantage over the stand method described in § 100.

Advantages:

- (1) It trains the working plans officer to think in terms of age and volume.
- (2) If broadly applied it may result in a good distribution of age and cutting series,* as well as a sustained yield and is very similar to stand selection.

Illustration. Since this method is better fitted for European forests which already been regulated under working plans, the student is referred to Schlicher III (p. 382 and 388) for examples of area and volume allotment. See also § 100.

99. Modern Allotment Principles. From a review of the modern allotment methods used in the various German states the following principles appear to have been evolved after years of regulation practice:

- (1) Area allotment is used only for simple regular stands; combined allotment (volume and area) is preferred for irregular stands.
- (2) Yield calculations are usually *recorded* only for the first period, though sometimes calculated for more as a trial balance.

(3) The age class table is the most important basis of the working plans for a timber forest; in mixed stands areas are classified proportionately to the age classes in selection forests estimated carefully, considering age or size class relation.

- (4) The normal periodic area, i.e., $\frac{\text{total area divided by number of periods}}{\text{years in period}}$

is the basis for the cut determination. If excess of mature stands or less than the normal area (and vice versa) may be allotted.

(5) Trees of main cut are calipered; intermediate cut estimated. The thinning series regulated by area and their yield estimated. The periods are usually 20 years.

- (6) Revisions of the cut calculations usually take place every 10 years.
- (7) The assignment of compartments or lots to the first period determined.

* It is taken for granted that the silvical needs for a proper cutting series are thoroughly understood and that under intensive forestry the age of the bordering stands must be planned long in advance.

condition of each stand, felling series, age class relation and natural phenomena, as well as area and volume.

Regulation by (Americanized) Stand Selection (after Judeich). The (or individualizing) methods may be defined as follows: *Each stand is selected for its maturity and designated for cutting provided other age classes exist to assure continuity of crops.*

Roth rightly considers "financial maturity" too narrow a conception of selection because the object of management may not be solely financial considerations. Actual practice in Europe seems to justify his position, for the selection of stands to be cut depends on a number of factors; (1) Financial maturity, (2) Technical or administrative needs, (3) Maturity judged by local age, soil and stand conditions, (4) Poor growth, felling series, full increment and normal conditions generally.

Roth calls this method "limited area allotment" and classes it as *an area allotment for the first period only*, while Schlich emphasizes the selection of stands for cutting on silvicultural grounds or objects of management. The method certainly progresses toward the normal if the method is intelligently applied. Roth says (p. 145) that,

It is usually claimed that this method only binds the action for the coming ten or fifteen years, while regular area allotment is claimed to be binding for an entire rotation. This is not true."

This is correct; paper work tabulation today would never be binding over long periods.

The amount to cut depends (in Europe) partly on the results of former cutting plans and partly on an area-volume check. No considerable error in over-cutting or under-cutting is likely with careful revisions every 10 to 15 years. To sum up, the cutting of stands is according to local requirements and is repeated at frequent intervals.

Advantages: (1) Stands may become mixed as to age class arrangement owing to the freedom allowed in selecting stands.

The sustained yield may be departed from if too much freedom is given to selections for cutting solely on silvicultural grounds.

Disadvantages: (1) The method is supple and broad gauge.

It can be readily applied under many existing American conditions.

Illustration of Stand Selection in Eastern and Western Forests. A. Eastern

Given: Irregular lots or compartments of white pine, old field spruce, and hardwoods in Northern New England, with an excellent market (except for spruce cordwood) and sufficient transportation. The white pine is to be naturally regenerated after clear cutting and the old field spruce clear cut and replanted. The hardwoods are to be retained as hardwood stands and are in need of heavy management fellings for the first 30 years of the rotation, which has been fixed tentatively at 80 years with the expectation of a reduction to 70 or 60 years after 20-40 years. Stock taking the lots were tabulated as given below. It must be realized, however, that within the lots there is considerable variation in age. Except for the small scenic object of management is to obtain the best financial returns compatible with a reasonably sustained yield. A small local sawmill is largely dependent on the forest for the high grade logs are shipped by rail to a larger mill. The resident forester is the manager of some 25,000 acres additional so must systematize his business. The forest is designated or marked for cutting under his direction and the logging done by contract with penalties for damage to reproduction or standing timber and for waste logging.

Lot No. (1)	Area Acres (2)	Age Class (3)	Forest* Type		Estimated volume**		Remarks. (8)
			(4)	(5)	M. Board Feet (6)	Cords (7)	
1	10	90	P	I	850	...	Thrifty, good increment
2	42	30	H	2	...	560	Fungus infected.
3	11	100	P	2	600	...	Scenic forest reserved for
4	8	120	H	1	(100)	(580)	Rapid growth & still very
5	16	60	P	2	680	...	Needs thinning.
6	15	40	S	I	300	...	Hardwoods in openings.
7	21	70	P	2	590	...	Fully stocked, thrifty.
8	81	20	P	2	...	...	Open stand.
9	20	70	PH	...	560	...	Mature, needs cutting.
10	10	100	P	2	620	...	One fourth stand dead
11	6	80	H	2	30	130	
12	33	50	P	2	850	...	
13	24	60	S	...	650	...	Fine thrifty stand.
14	25	50	P	2	640	...	
15	17	60	P	2	400	...	Poorly pruned.
16	12	30	P	3	100	...	
17	18	40	P	H	470	...	
18	60	30	P	2	154	...	
19	30	50	P	3	580	...	Ridge, slow growth.
20	25	30	P	I	243	...	Some windfall or snowb
21	35	60	P	2	820	...	
22	36	80	S	...	1,150	...	Trees stunted due to lack
23	28	60	H	2	120	710	(thin)
24	45	40	P	2	740	...	
25	60	20	P	I	270	...	Planted in 1900, very reg
26	45	50	S	...	900	...	Some windfall.
27	32	40	P	3	320	...	5 acres fire killed.
28	100	0	H	3	...	...	Burned over 1919.
29	75	50	P	3	900	...	Birch in openings.
30	60	20	P	H	220	...	Very wet soil, liable to w
Totals 1,000					13,750	1,400	(Scenic forest not added)

Before making a decision what to cut during the next 20 years, a number of factors must be carefully weighed. The figures are approximations only for purposes of illustration.

(1) Age classes. Dividing the forest into four age classes of 20 years each, we have the following acres in each class:

"I Period"	"II Period"	"III Period"	"IV Period"
61-80 years and over	41-60 years	21-30 years	1-20 years
122 acres	328 acres	249 acres	301 acres

The "normal periodic area" is $\frac{1000}{80} \times 20 = 250$ acres, or $12\frac{1}{2}$ acres per year. The

III period is nearly normal, while I is very deficient.

(2) Growth. For an approximation of hardwood volumes and growth the base is as follows: Hardwood quality I, 1 cord per acre per year (if fully stocked); hardwood quality II, .7 per acre per year; hardwood quality III, .3 per acre per year. It is assumed from local data that $\frac{1}{3}$ the hardwood yield in stands 50 years or over will be board feet and $\frac{2}{3}$ cordwood. White pine growth is from Bulletin 13, Forest Service. The spruce if fully stocked is estimated at 500 board feet per acre per year. The mean annual growth on the whole forest is estimated at 250,000 ft. (from the Forest Service Bulletin 13, already referred to; reduced to conform with present stocking). The normal growth should be about 360,000 ft. B.M. (cordwood excluded).

(3) Growing stock. The actual growing stock, reduced to a common factor of board feet (counting 3 cords as equal to 1,000 board feet, obviously a rule of ratio based on local conditions) is 13,750 M ft. B.M. and 1,400 cords or total of 14,150 ft. B.M. This is based on actual calipering on 20% of the area where over 30

* Key to abbreviations used: PH = Pine and Hemlock; H1 = Hardwoods Site I; H2 = Hardwoods Site II; H3 = Hardwoods Site III; S = Pure Spruce; P1 = Pine Site I; P2 = Pure Pine Site II.

** From tables for white pine, page 23, Bull. 13, Forest Service, figures evened

on ocular guesses in stands 30 years and under. It is clear that the hardwood problem is not a serious one, since it can be sold locally on the cutting areas. Normal growing stock (estimated by one of the methods already described) is 14,400 M ft. for a rotation of 80 years; the apparent approach to normality of actual growing stock is because there are stands past the rotation age with high growth per acre.

Cutting series is not considered except that in the spruce stands a shelter belt of hardwoods is left on the N. W. to protect the spruce from the heavy spring storms so frequent in the locality.

How much to cut? Where to cut? Because it is likely that the growing stock decreased (since it is anticipated that the rotation will be decreased from 80 to 40 within the next 40 years), it is proposed to cut the following lots (cutting order list to local forester) from 1920-1940 which it is estimated will yield the amounts

Acres	Av. age when cut	Yield		Reason for cutting.
		M. bd. ft.	cords	
10	100	850	..	Should be cut last since growth excellent.
11	110	600	..	Needs cutting, fungus infected.
8	130	20	10	Dying and down timber only to be cut.
21	80	590	..	Open stand with advance regeneration, part of area needs replanting.
20	80	560	..	Open stand.
10	110	620	..	Fully mature.
6	90	30	130	Dead chestnut will be lost unless cut at once.
36	90	1,150	..	Growth very slow.
122		4,420	140±	
122	6.1	221	7	

Recently the area cut over is too small and the age class distribution will be distorted, but it should be noted that lot No. 28 has just been burned over and comprises 100 acres, which plus $122 \div 20 =$ an annual cut of 11.1 acres while the normal is 12.5. The volume to be cut comprises favorably with the mean annual growth: 100,000 of main cut plus half the growth of the stands cut for 20 years or about 100,000 and an estimated 2 M ft. per year from thinnings or a total of 249,000 ft. B. M. There was considerable doubt about the advisability of increasing the cut, so low cutting other stands which were overmature and declining in vigor, proper management would probably justify largely exceeding the mean annual growth. It should be recognized that in New England stumpage prices may double or triple in thirty years from now when the bulk of the best timber used must be transported to the Pacific Coast. This is an argument for retaining a stand (such as is found in lot 28) that is growing thriftily, notwithstanding the fact it is well over the rotation age. In this instance further checks are hardly necessary but might be applied before making a decision on the cut. It must be emphasized that the answer given to the particular problem is not necessarily the one and only correct solution. A good management should depend on the minute local circumstances. But in any case, it is clear that the table of lots that there will be ample merchantable timber for future cutting for 100 years have elapsed.

For further illustration of the broad application of the stand method to a forest for long-term management for more than 10 years, reference is made to appendix B, especially to the tabular summary of forest types by area and age given in Bulletin 1099, Harvard Forest. In 1909 Professor Fisher estimated the mean annual increment in the Harvard Forest at about 250,000 board feet and cut that amount for ten years, i.e., 2,500,000 feet. The estimated growing stock in 1919 was 12,435,000 and only 100,000 in 1909, an increase of 1,935,000 which plus 2,500,000, the amount cut, gives a total of 4,435,000 $\div 10$ years = 443,500 ft. B. M.; so the cutting of only 250,000 was very conservative and the forest is being enriched and built up. But part of the increase is perhaps due to trees (which had no board foot value) reaching merchantable size through increase in diameter. The clever classification by forest types subdivided into "tracts" and age classes is worthy of adoption under similar conditions. *Western Forest.* Let us suppose that in 1920 an Arizona western yellow pine forest of 10,000 acres (within a National Forest) is divided into four age classes which are approximately separated and mapped (based on strip surveys for 10% of area) as follows:

Age Class (1)	Age Limits (2)	Area Acres (3)	Per Acre (4)
	<u>200-360</u>		
(A) Overmature (merchantable)	300	4,000	10,000
	<u>140-199</u>		
(B) Mature (merchantable)	180	2,000	12,000
	<u>20-139</u>		
(C) Immature ($\frac{3}{4}$ merchantable)	100	2,000	7,000
(D) Reproduction (no merchantable trees)	1-19	2,000	0
Totals		10,000	7

This condition is typical of many forest areas in the United States but class (B) would be usually grouped as one overmature age class, and an accurate separation of age classes is often impossible (see Part II of this book).

The established rotation is 200 years. A local sawmill (cutting 8,000 M per acre) must be supplied with timber under practical logging conditions, and it is desirable to retain the sawmill as a permanent local industry. Dividing the total stand (10,000 acres) by the area (column 3), we have an average stand of 7,800 ft. per acre. Cutting all the overmature timber. Since the logging (owing to silvicultural requirements) must remove all the overmature timber, about 80% of the mature and 10% of the immature (thinnings and improvement cutting of diseased trees), the average acre will be $4,000 + 1,920 + 140$ board feet or a total of 6,060 and will leave under 100 feet B. M.

From extensive sample plots on land cut over under existing conditions we find that the growth is approximately from 41 to 141 board feet per acre depending on the percentage of immature stands of rapid growth. As a rule of thumb,

$$\frac{41+141}{2} = 91, \text{ or say } 100 \text{ board feet may be assumed. On } 10,000 \text{ acres of cut}$$

land the current growth would be about 1,000,000 feet per year. Dividing 10,000 acres by rotation age, $\frac{10,000}{200} = 50$ acres to be cut each year. Assuming 6,060 as the

average growth, $6,060 \times 50 = 303,000$ board feet, which is less than $\frac{1}{3}$ the estimated current growth after logging (if the whole tract were rapidly cut over, say within 5 years). This is a further complication in that the rotation may later on be reduced to from 100 to 160 years owing to protection from fire, sheep grazing and the judicious thinning of immature stands. Moreover, under present conditions it is assumed practical logging requires a cut of at least $2\frac{1}{2}$ million bd. ft. per section (640 acres) or about 4,000 M per acre.

What annual cut should be allowed? Classes (A) and (B) cover 6,000 acres and contain 64,000 M feet. The 10% cut from class (C) is omitted from consideration since a cut of 140 board feet additional is practically immaterial to the answer. The rate of cutting, the greater the losses from death, windfall, misletoe, etc. in classes (A) and (B), but the greater the hiatus in cut, when this overmature stock is removed.

Case (a),	If (A) and (B) are cut in 10 years	the annual cut is	5,920,000 + thin-
" (b),	" " " " " " " " " " " "	20 " " " " " "	2,960,000 +
" (c),	" " " " " " " " " " " "	30 " " " " " "	1,973,000 +
" (d),	" " " " " " " " " " " "	40 " " " " " "	1,480,000 +

If class (A) only were cut the yield would be 4,000 M if cut in 10 years, 2,000 M in 30 years, 1,000 M in 40 years; with thinnings added in each case. Cutting timber in class (A) in 20 years the cut per acre would be 4,000 ft. our minimum logging requirement. Ten years is certainly too short a period and 40 too long because class (A) will suffer through death and disease. The choice then lies between 20 or 30 years. The final choice we will assume should be 20 years because it prolongs the cut and gives an ample cut per acre, and by commencing sales in areas where most of the overmature timber is found, the loss through overmaturity is minimized. More important, it is possible to cover the whole transaction in a 20-year timber sale.

(Solution No. 1). The cut will then be, 2,960,000 (from A & B) + 70,000 (from C) = 3,030,000 per year (500 acres or $\frac{3}{8}$ the necessary supply to run the mill). The governing factors have been overmaturity of timber which has necessitated cutting 10% of the normal area of 50 acres (or $7\frac{1}{2}$ times even if the rotation were reduced

The decision, obviously a compromise, is wise silviculturally and economically, the regulation standpoint leaves much to be desired. It omits any attempt to be to loss from decadence, growth during 20 years cutting period, etc. since it appear necessary to have more exact figures. If yield tables are made, the of decadence and growth are easily approximated. One of two things must done. The mill must buy private timber or the government must increase the he working circle to about 26½ thousand acres with the understanding that at of 20 years (1940) the capacity of the mill must be reduced to the capacity of the a reasonable restriction. It is even possible that in 1940 the character of will have changed and the logging railroad in use will be scraped and ing conducted by small gasoline mills with motor transport. In other words, 10 M cut of the present mill should not influence the solution of the problem 40.

on No. 1 is based on a compromise clearly recognizing the necessity of a com- adjustment after the overmature timber is salvaged. If there were no additional or public stumpage available and if the mill would be forced to shut down on a million per year (but could operate on 6 million) the cutting of class (A) and ght have to be sanctioned in 10 years. The problem as solved is really on the the Americanized stand method and without holding overmature timber so as ize the cut 20 years from now—a transition period of cutting is frankly acknowl- s a necessity to prevent loss through decadence. The preliminary cutting cycle ars. It should be clearly noted what the age class and stand condition will be nd of 20 years if this solution of the cut is adopted. For the sake of simplicity, ngement of age classes already used is followed:

Age Class	Age Limits	Area	Volume Per acre	Board Feet Total
A	0-19	4,000	0	0
B	160-219	2,000	2,880*	5,760,000
C	40-159	2,000	9,000**	18,000,000
D	20-39	2,000	1,000**	2,000,000
als		10,000		25,760,000

ass B been uncut, the stand in 1940 would have been about 45 million, a far ple figure from the standpoint of regulation and much better adapted to continue nably sustained yield. But in the example given this was sacrificed to give a ut per acre and to avoid loss in mature timber.

fundamental error made by some foresters in their calculations is that they at that the answer today must be completely and logically worked out for con- 20 to 50 years from now, which it is reasonable to suppose will be totally t and unquestionably much more intensive than we can bring ourselves to realize. re forest conditions in 1870 with those of 1920 and see what a great change is in

tion No. 2.) Now suppose that the working plans officer wanted to make some e in order to ensure a better sustained yield in the future and so as to avoid us or lack of merchantable stands, which would occur with solution No. 1. Let er suppose that the normal growing stock on 10,000 acres averages 7,000 feet e or a total of 70,000 M ft. By comparing this 70,000 M ft. with the total of (5) in the first table, it is seen there is an apparent surplus of 8,000 M ft. But ring there is 40,000 M of overmature timber (age class A), it is evident that even deficit in real producing capacity actually exists, and a very serious one. In No. 1 we cut 6,060 feet per acre or 77% and left 1,740 feet or 23%. Granted ld change our silvicultural methods, let us see what we could do to secure a sustained yield in the future by the following plan: cut all of (A), 20% of (B) % of (C) as before. Make the cutting cycle 30 years. Our cut would then be s evened off) as follows:

$$10 \text{ M} - \frac{1}{2}(2,810^{**} \text{ feet} \times 4,000 \text{ acres}) + \frac{2}{10} (24,000 \text{ M})^{*}$$

$$\frac{1}{2}(\frac{2}{10} \times 2,000 \times 2,000 \text{ acres}) + \frac{1}{10} (14,000 \text{ M}) = 40,980 \text{ M} \div 30 \text{ years}$$

3,666 M per year (this solution thus gives less than half the yield given in plan

per year growth added to 20% of 12,000 ft. per acre. This figure however had obtained from yield table.

ad from yield table. 5% cut in thinnings, etc. is not deducted because this is in (being saved from loss).

loss here from 10 M per acre to 7,190 board feet over a period of 30 years.

with from 12 M per acre to 14 M.

No. 1). To get our cut of 8,000 per year, we adopt the equation $\frac{1,366}{10,000} = \frac{8,000}{x}$ when solved for x gives an answer of 60,000 acres in round figures, for the v circle. Now if we cut as indicated commencing in 1920, the condition of the forest in 1950 will be as follows:

Age class (1)	Age (2)	Area acres (3)	Per acre year 1950 (4)	Total (5)
A	1-20 15	4,400	.....	.....
B	170-220 210	1,600	14,000	22,400
C	50-169 130	2,000	2,000	4,000
D	30-49 40		10,000	20,000
		10,000		46,000

In this case we have cut $4\frac{1}{2}$ M per acre removing but 57% of the stand but the is left in a much better shape for regulation and probably for regeneration, as we have only lost 4.8 million feet from decay, etc. in Class (A). This loss will probably be more than made up by an increase in stumpage price. Yet our growing stock is still much less than normal. With $4/10$ the forest stocked with an overmatured stand it would be unwise to try to bridge the gap made by our getting rid of the overmatured Class (A). This solution No. 2 is better than solution No. 1 judged from the point of future regulation. Yet even in this case we are left after the first cutting cycle with insufficient growing stock and too many young age classes. We will have 0-50 years, 64%; 51-100 years, 0; 101-50, 20%; and 151-200, 0, but 16% at the 210. This is typical of the age class confusion that results after cutting in virgin forest even when "conservative logging" is followed. Were it possible to reduce the rotation to 150 years, then the situation would be less serious, and even as it stands, it is possible to whip the forest into more normal condition as the rotation proceeds.

102. Differences between Area-volume Allotment and Stand Method.

Originally used the area-volume allotment recorded the areas and amounts cut for all the periods. Today allotments are usually made only for the first period at most the second period. In other words, it approaches the stand method where the cutting is arranged for 10 to 20 years only. In making allotments the main stress is on equal areas and equal volumes to be cut in each period. With the stand method the main objective is to select stands in financial and technical need of cutting. Another difference is that the yield in the allotment method is largely based on a comparison of areas and volumes, while in stand selection the cut may be based on equal cutting areas, on

* In Oregon it is likely (according to Weidman) that clear cutting of western white pine to free the advance regeneration would be a sound silvicultural system. Seed trees may be retained on the chance that fire might destroy the existing growth. It is therefore anticipated that the present system of periodic cuts every 40 or 60 years in the many-aged yellow pine climax type will be abandoned, because the next crop will be *even-aged*. Under these conditions how will a sustained yield be secured? The problem is readily solved. (a) Divide the working circle into convenient compartments. (b) Decide on the rotation. (c) Adopt a cutting cycle. (d) Cut the most mature timber first. (e) Regulate the cut by allotment to periods (or by the stand method) frankly admitting that the present yield is preliminary and must be radically readjusted when the (excess) mature growing stock is removed.

growth if the age class distribution is fairly normal, or on any established method of gauging the cut.

Formerly there was thus the rigid allotment "framework" but today the allotment and stand methods tend to become more and more similar.

Use of Age Classes in Regulation. The various Hufnagel methods described in detail by Recknagel in his "Forest Working Plans" (pp. 100, 101) are of interest, since they introduce new ideas of regulation, but the problem will be reduced in the final analysis to using the stand with allotments of age classes to the current cutting cycle or (if the age class distribution happened to be fairly normal) to the proportionate share of rotation, as with the French method of 1883. Even in American forests, empirical age classes may be distinguished and separated relating age with diameter as given in § 160, and then the age class is allotted for cutting as if a distinct stand. This plan was the basis of Professor Chapman's so-called "American Method" as it was first devised in Part II for present revised "American Method of Horizontal Cut").

It is of value to remember that in uneven age stands; (1) the volume of one or more mature age classes chosen for cutting divided by the (a) years of cutting cycle or (b) their proportionate share of the years in the stand or (c) years in the period to which these mature age classes are allotted for cutting, gives an indication of what can be cut.

The volume of one or more mature age classes chosen for cutting, divided by the area they occupy, gives the average cut per acre; and if multiplied by the mean area to be cut over gives an indicated check on the volume that can be cut under given conditions.

The normality or abnormality of age classes, after their average age class volume is obtained, can be checked by comparing the areas they occupy. The relative area occupied by the merchantable age classes is obtained by dividing their actual total volume by the empirical yield table figure for the age (see chapter XII).

When age classes are allotted for cutting, a figure equal to half the volume (or loss through decadence) while they are being cut should be added or subtracted from) their volume. Owing to the generally unknown and variable factor of natural loss of numbers in forest stands, it is dangerous to relate current growth to diameter classes in order to compute future growth except for very short periods, followed by stock taking and a readjustment of figures.

Regulation on Basis of Cutting Cycles and Felling Reserve. The term "American method" is defined by Professor Chapman as follows: "the determination and equalization of the annual cut on basis of volume, by means of varying the length of the first and second cutting cycles, and determination of the annual cut by using the principle of a felling reserve and cutting series, and of an allotment of areas or stands for cutting within the period."

Discussion. The whole of Part II of this volume is devoted to a very detailed treatise on the foundations of the "American method," the conditions governing its application, with very complete illustrations of the plan as actually applied. There is also considerable detail regarding the correlation

of age with diameter, and yield table volumes with stand estimates, in order to predict growth and correlate growth with our irregular and perverted extensive stands. This mass of data teaches the student to think regularly in terms of cutting cycles, age classes, per acre growth in board feet, future sustained yield; it is a correlation of growth and regulation in extensive stands. But where age classes can be differentiated in the forest at a reasonable cost and cutting cycles largely reduced from the extremes of $\frac{1}{2}$ to 100 years then the "American method" does not appear necessary. Furthermore, during the first cutting cycle it may be necessary to sacrifice some regularity of cut in order to save overmature timber that will otherwise be lost through decay, windfall, and other natural accidents to the stand? Judging from § 154, Part II, this loss would amount to at least one-fourth the stand if ripe western yellow pine trees are held 100 years beyond rotation age. As a matter of fact, the actual loss, though often exaggerated, is sometimes also far greater, because the soil covered by the veteran stand is not only actually losing timber, but is occupying space that ought to be producing a rapidly growing young stand. Moreover the longer overmature stands are held, the more difficult will be regeneration, which with high costs and extensive areas in the West, must be secured largely by artificial regeneration. Therefore deliberately planned cutting cycles of fifty to one hundred years are economically unsound, when not absolutely forced by special conditions.

For example in § 176 the cut for a second cutting cycle is worked out for lodgepole pine. There is no objection to this merely as a trial balance; of course it must be recognized that in the second cycle (1940-1980) there will be clear cutting, intensive thinnings and probably the use of the French method or stand method of regulating the cut.

Professor Chapman has given an illustration from the Coconino National Forest (Arizona) considered as a whole. Ultimately there will probably be extensive and intensive two classes of local conditions, namely, (a) intensive and (b) extensive. If this prediction is accepted as likely, then the two classes of conditions must have been recognized today by varying the length of the cutting cycle in different portions of the forest. At least this can be done within the next 100 years. To presume that a cutting cycle of a hundred years will continue in the West, seems absolutely improbable. There is another important factor in policy to be considered in weighing a method. How much accuracy is justified in extensive conditions? To my mind a rather crude method will give rule of thumb results sufficiently accurate if the more accurate calculation means an appreciably greater initial expense. Take a case in point—the amount to cut on the Coconino Forest (par. 166). According to Chapman, the French method of 1883 indicated 28 million feet as the correct cut, Von Mantel's crude formula 31½ million, the Austrian 38½ million, the American method 27, the last figure being assumed by Chapman as the correct cut. The mean annual growth was computed to be 42½ million feet. Who would say that the French method is not sufficiently accurate in this particular case? And cannot the forest be split up into a number of small working circles? And should not the cutting cycle of 100 years be reduced

Furthermore, if we allow the regulator to guess at the future, it is that with fire protection, protection from destructive sheep grazing, logs, some planting or sowing, and with better methods of silviculture, will probably reduce our 200-year rotation to from 140 to 160 years. However, today we know for a fact that much of the growing stock is in mature stands. Why not cut 35 to 40 million and get rid of the mature faster? Can the Forest Service justify the smaller cut of 27 million? This is extremely doubtful. This discussion, which admittedly leads to argument, merely tends to show the student the danger of placing too much emphasis on regulating the cut by mathematics, as opposed to the needs of silviculture and policy. The administrator must base the final decision on a compromise between regulation mathematics, silviculture, and policy. Whatever the answer, it is at least difficult to justify holding the overmature timber longer than necessary. Just now should not silviculture come first? Even in Europe the tendency is towards silviculture rather than towards rigid regulation.

The great similarity between Chapman's former "American method," as described by Recknagel, and the French method of 1883 is evident. In 1917 it was really an allotment of diameter classes to irregular periods (gauged by years allotted to each age class) instead of a straight volume-area allotment. But the method has been considerably modified from time to time. In 1920 Recknagel said regarding it that it was ".....an adaptation of the French volume-period methodbut greatly simplified." Today it sizes cutting cycles and felling reserves. By demonstrating the ease of determining diameter, age, and growth in irregular stands Professor Chapman rendered a great service. For the details of the American method the student is referred to Part II, which follows, and which contains an immense amount of valuable and sound *mensuration*, besides a philosophical discussion of the application of regulation to extensive American stands.

In studying the methods described in Part II it is important to visualize the probable future development of permanent *transportation* in the South and West. It is confidently predicted that permanent transportation must be secured within the next half century, for without it forest management will prove a partial failure. The building of *temporary* logging railroads and the elaborate plan of cutting cycles 50 to 100 years in length will surely result in the failure of forest regulation, because *permanent transportation* is the foundation on which our future continuous forest production and stable forest industries must rest. Moreover it must be admitted that the regulation plans of Part II may be gradually replaced by the allotment method when a clear cutting system becomes more general with certain species, as it must eventually. But it must be recognized that the present clear cutting means a delay in harvesting the stands in the last

.*

For all clear cutting silvicultural systems an allotment, simple area, or stand method is usually employed. For selection felling the French method of 1883, or a variation of it, or the new "American Method," may be used if formulae methods are

105. **Quiz.** Why is volume alone an unsatisfactory basis for regulation?
 Is area alone satisfactory?
 Explain regulation by fixed areas?
 When should it be used?
 How does area allotment differ from regulation of cut by fixed areas?
 Explain area allotment.
 Why is an area-volume basis of regulation more satisfactory than volume all?
 Explain deficiencies of volume allotment.
 Cite the more important principles of allotment methods as applied in Germany.
 Give disadvantages and advantages of area-volume allotment.
 Define stand selection; what is its basis?
 Why is the stand method a good scheme of regulating the cut?
 Illustrate conditions which would fully justify its application.
 What is the essential difference between area-volume allotment and the stand method?
 What is the basis for the "American method" of regulating the cut?
 What are its weaknesses? Its strong points?
 Is it a permanent or temporary method of regulating the cut? Why?
 (See Part II for further and detailed quiz questions.)

considered undesirable, but see also Part II for methods which are recommended by Chapman. The frank discussion of the "American method" will not be misunderstood by those who have read H. G. Wells' recent "Outlines of History." (See § 101.)

When checking over my references to his own writings Professor Roth made valuable suggestions. Every student of regulation should read Roth's article, October, 1921, *Forest Leaves*.

PART II

CORRELATION OF REGULATION AND GROWTH IN EXTENSIVE AMERICAN FORESTS

BY

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CHAPTER X

THE CUTTING CYCLE AS A DETERMINING INFLUENCE IN AMERICAN FOREST REGULATION

Attitude of Private Owners. Forest Regulation in America with the idea of securing a sustained yield is as yet but little understood by private owners. The idea itself marks such a departure from accepted standards of practice, and entails so many apparent risks and sacrifices of immediate gain that it is usually rejected in favor of a more rapid realization of value by cutting mature timber. The private investor understands stumpage

He does not yet grasp forest values, and seeks to convert stumpage into terms of property and investments with which he is familiar.

Preliminary Requirements. Before regulation of cut to secure sustained yield is possible on forest properties in this country, several preliminary requirements are necessary. First comes the acquisition, establishment and management of a forest estate of sufficient size to justify management as a business financial venture rather than as a side issue to some other source of income such as farming.

Permanence of ownership, which in this country is sadly lacking, and public policy, which here means a more complete acceptance of the economic and technical basis of forest production, is next in importance. As yet, tracts of sufficient size when managed for timber are usually not intended as permanent holdings. This is the case with the vast bulk of lumbermen's lands, and often those which might constitute true forest estates are chiefly reserved to the owners as parks or for game and fish preserves.

Improvement of markets and of accessibility by better transportation is next. On tracts where in the past but a small percentage of the available logging timber by species or sizes could be marketed, no permanent plan for

sustained yield was possible. The final development of stumpage value, the main body of the timber will alone permit of the intelligent consideration of regulation of the forest.

108. Obstacles to Regulation of Yield. One of the greatest obstacles to regulation of yield is the character of the forests themselves; the fact so far the cut has been largely from virgin forests often of mixed species instead of from second growth produced artificially or grown as even stands free from suppression. The difficulties are:

First, a surplus of overmature, usually decadent timber which now requires rapid removal leading to and establishing the custom of overcutting but is accompanied frequently by a deficiency in younger age classes, tends under any method of regulation to perpetuate an abnormal composition leading to a reduction of the cut below the normal sustained output and expiration of the first cutting cycle.

Second, the extensive character of investment and of operation indicates in order to remove this surplus of large stock economically and properly to render the largest possible area accessible by reducing logging costs in order to realize the greatest stumpage value. The rate of annual cut so established and the rate of depreciation on the investments required usually tend to exhaust the growing stock completely in a period far too short to secure a continuous sustained yield. This does not preclude forest management, for it is possible to secure on such cut-over areas a renewal of forest growth by natural or artificial reproduction. It *does* substitute periodic or intermittent yields for regular annual or sustained yields. Where transportation continues to be expensive, a permanent policy of periodic rather than sustained yields may be necessary, with intervening periods during which practically no revenue is realized from timber cutting.

Third, the absence of data on the rate of growth of the forest prevents the determination of the proper annual cut by which sustained yield can be secured. The problem is to prolong the first cut on virgin forests until a second cut can be made on areas previously cut over. To determine the length of this period, the rate of growth of timber left on cut-over land and of reproduction, is required—while to determine the amount which should be cut annually *during* this period, the rate of growth of the timber standing is needed. There are considerable difficulties in the way of solving both problems, and until this data becomes more reliable, the regulation of the cut on virgin forests will be equally unreliable.

Effect of over-cutting. On forest areas which have already passed through this first cutting cycle, especially where the processes of cutting have resembled those of forest denudation, the problem of regulation of the cut is indefinitely postponed until the establishment or re-creation of a growing stock can be regulated. Silviculture, not regulation, is the important consideration on such depleted forests.

Regulation of yield in this country can be applied at this time only to forests which have not already been cut over, or on which a second growth is approaching maturity, hence the problem first in importance is one of providing a gradual transition of a virgin forest to one capable of permanent

yield, in place of the process of overcutting which involves a subse-
low and discouraging period of restoration of forest capital.

Policy as Influenced by Character of Ownership. *Owners who can Sustained Yield.* Under present conditions in America the classes of who can best afford to prolong the cut of virgin timber so as to com-
bridge the gap between first and second cuttings are public owners and
owners whose principal investments are in some form of manufactur-
dependent on wood, and who desire to own and control a sufficient supply
are the perpetuation of their business. Public forests stocked with
timber and managed for commercial production lie chiefly in national
ship, and should always be managed for sustained yield unless it can be
ely shown that such management would prevent the proper exploitation
timber and permit it to go to waste unused.

Policy for Other Private Owners. But with private owners, other than the
mentioned, the course apparently indicated is, first, a considerable reduc-
the investment in overmature, merchantable forest capital, second, the
ation of young thrifty timber and the reproduction of the forest by
silviculture and protection, third, the final restoration of the forest
by growth.

impractical for such typical forest owners as the majority of lumber-
to curtail the rate of cutting to a point which will permit of sustained
during such period of transition. The one item of taxes on mature tim-
nds to prevent this, even without the additional costs due to losses in
and interest charges. But this economic justification of overcutting
it doubly difficult to check the process of denudation in time to secure
uction, and ultimate restoration of the forest capital. With the exhaus-
the growing stock, the owner's interest is gone. He has never grasped
ea of forestry as a sustained business of timber growing. For practi-
all private forest owners whose interest in forests as productive property
based on larger outside investments, sound management demands not
mplete removal of the merchantable capital, but rather the determina-
the *largest per cent of young timber which it is possible for them to leave*
second cut. By this means the *value* tied up in the investment can be
ed, yet its *future productiveness* preserved, and not only will the repro-
n of the forest be made more certain but the period which must elapse
a second cut can be made will be greatly lessened.

this form which tends to future, though intermittent yield, the regulation
d is already being practiced by many private forest owners, and should
iversally and immediately adopted by the remainder. On denuded
lands, regulation will be postponed until the growing stock is built up
point where there is something to regulate.

Policy of Private Owners. It is evident that in this transition of a virgin forest
regulated forest, the process, both as to speed and thoroughness of execu-
not an end in itself, but a means of making the property more useful and
able, and of accomplishing to a greater degree the purposes for which the
ess involved in its management is conducted. It is a basic premise that
orest land cannot be as profitably used for any other purpose as for tim-

ber production and often has no other use whatever. On this basis its present denudation is not profitable to the future owners, whoever they may be, whether public or private. Hence, clear cutting can profit the present owner only in the sense that he is a wrecker of a going concern and intentionally sacrifice the permanent assets, that is, to abandon the land, or sell it and junk the enterprise.

If the present owner once recognizes this responsibility or trusteeship of the land capable of growing crops of timber, his entire attitude toward the management of forest land must necessarily change. This does not involve an immediate attempt to secure *present sustained yield* or complete transition to a regulated forest, but it will mean the careful appraisal of the possibilities of forest management for production of timber by growth, its costs, the relative profitableness of logging small versus large timber, and the measures required to secure, at some future time, a second cut of timber, and the extent to which the period which must elapse between cuts can be shortened by curtailing the present operation. In all of this, the primary consideration must be financial, a question of returns on the investment. But there must be no deliberate intention to destroy the possibility of forest renewal.

110. Goal of Public Management. But with public and especially national forests, no such limitations exist to prevent the immediate application of the principle of complete transition to a regulated forest by proper control of the original growth. The public purposes of management are primarily for public benefits through the yield of forest products, not through profits from the sale of timber. With lower interest rates and the emphasis shifted from the side of income to that of production and supply, national and other public forests *must* be managed to obtain sustained yield, and the annual cutting must be regulated before it threatens to exceed the capacity of the forest to meet the requirements of the transition period.

111. Influences Determining Initial Cut per Acre. In the practical application of regulation either to virgin forests or to restocked areas, the owner is at once called on to determine the character and severity of the first cutting to be permitted. Even on public forests, logging cannot be conducted at a loss. In such case it should not be conducted at all, but must be conducted by purchasers of stumpage or at public expense. Timber which must be logged at a loss is in effect inaccessible until economic conditions change.

In direct proportion as the cut per acre and consequent total cut per logging unit is increased, the logging costs per unit of product are reduced, the accessible area thereby extended, and the marginal value of stumpage enlarged. But at the same time the stock remaining after cutting is reduced, the period required to produce a second cut is lengthened, the risks of fire, slash and insects increased and the difficulties of obtaining sustained yield multiplied.

Whatever tends to increase logging costs and thus reduce the margin between such costs and sale value of the logs or lumber tends to require a heavier first cut per acre. Transportation has the greatest effect on logging costs. Permanent road systems have seldom been provided as yet.

means of transportation is the rule, and the entire cost of such fixtures is borne by the stumpage logged in the first cutting. Where these conditions demand so severe a cutting that the possibility of natural reproduction would be destroyed, private owners are accustomed to proceed with this forest destruction. Where such conditions are true on public forest, the timber should be reserved for an increase in marginal value and not cut until it can be logged in a manner which will safeguard the future stand.

From the standpoint of the best silvicultural treatment of the forest, it frequently happens that natural reproduction is most easily obtained and is best when a fairly heavy cut is made, and that too conservative a cut per acre leaves the forest still in a stagnant condition, retards renewal, and unfavorably affects its composition. In other cases a more conservative cut is indicated. If forest management is to be practiced at all, the cut per acre cannot exceed the minimum which will leave the forest in condition to regenerate itself by reseeding unless it is definitely determined that artificial regeneration following clean cutting is the most desirable practice.

These two practical considerations, lumbering, and silviculture, come first in determining the exact nature of the problem of regulation confronting any private owner. Together, they determine *the per cent of the stand to be taken in the first cutting*. Neglect of the need for regulation would induce the owner to take too heavy a toll of the forest, while, on the other hand, over-emphasis of sustained yield, to the neglect of the actual practical conditions governing both the utilization and reproduction of the forest, might erroneously indicate a cut far too light for sound management.

The Cutting Cycle. Definition. Length. By definition, the cutting cycle is, first, the period elapsing between two successive cuts on the same logging area or logging unit, and second, the period which is required for logging operations to go once over the entire working group.

In order to obtain a sustained yield, these two definitions must both hold true; for if the period required for cutting operations to go once over the entire stand is shorter than the number of years which must elapse between successive cuts on the same area, intermittent yields with intervening periods of sustained cutting will result.

In order to return for a second cut on an area, there must be some timber left to turn over. While the first cut, which may remove a large surplus of over-mature timber, will normally exceed the second, yet the second cut must leave a sufficient quantity per acre to pay the cost of going after it, just as in the first operation.

The length of a cutting cycle based on a plan for continuous cutting or sustained yield will therefore depend first on the per cent of the original stand which is removed; second, on the character and age of the stand left on the land; third, on the rate of growth, after cutting, on this residual stand and on the growth of immature timber and reproduction. Upon these factors depends the length of the future crop and the period required to produce it.

Growth on Cutover Lands. To determine this period thus requires knowledge of the growth which will be secured on *cutover lands on the basis*

of area. Otherwise, the determination of the period before a return is possible is but a guess. The first effort in American regulation for sustained yield must therefore be directed to obtaining the basis for growth prediction from the trees left on cutover lands and on stands of immature timber. It is not to decide upon a given period for cutting the present volume in the future, but to get us nowhere, unless we know just why the said period is chosen. It gets what will happen when it is ended. The logger usually knows about how long a cut he has. But the span of life of the logger's operations is not the *relation to the next cut*. Regulation is an attempt to prolong logging until the second cut is ready and knowledge of growth is the key to this problem, whose solution must precede intelligent regulation.

114. Growth on Virgin Forests. Intermittent Yields. The second method is to determine directly how much can be cut annually from the virgin forest in order to round out or prolong the cutting to the year of beginning the next cut. If it is found that the indicated cut per year is too small to permit economical and efficient logging, then sustained yield will probably give way to intermittent yields. But to determine the true permissible annual yield, the change in volume of the stand by growth or decadence during this period must be approximately known, else the cut is more or less approximate. This requires a separate study of growth in the virgin forest. This is no less important than the study of growth on cutover lands which determines the length of the cycle,—it merely aids in carrying out the intention to complete the cut in this given period, without having it either fall short or overlap.

The solution of this double problem of growth may be sought either on the basis of accurate and painstaking investigations, or in their absence upon such approximate evidence as can be obtained pending more definite determination. The point to be emphasized here is that without the *decision*, first on the length of the initial cutting cycle, second on the limit of the annual cut during this cycle, there can be no effectual progressive regulation of yield, but only general assumptions based on crude suppositions such as that expressed by Von Mantel's formula. (See paragraph 82.)

115. Relation between the Cut per Acre and the Cutting Cycle. The determination of the rotation is itself the result of growth study. Without the rotation, not even these rough and ready methods of approximation such as Von Mantel's, are possible. But the cutting cycle takes into immediate account the *actual condition* of the entire area, with especial reference to the distribution of existing age classes and the proportionate area stocked with young timber. This the rotation alone does not do.

A short cutting cycle means a relatively small cut on each acre which is made over in a given logging operation, and the corresponding spreading of the cutting over a proportionately larger area in each year to cut the same quantity annually. Permanent road systems coupled with intensive demand permit of cutting cycles even as short as six to eight years. Conversely, a large cut per acre and concentration of the annual cut on a small area demand a lengthening of the cutting cycle in the same ratio. American forest regulation since it is primarily concerned for the immediate present with

ng stands of virgin timber, which are comparatively inaccessible, will d largely on a heavy cut per acre and a correspondingly long rather short cutting cycle. Conditions similar to most well managed, artigrown and accessible European forests, with short cutting cycles, will the regulation of the more accessible second growth forest areas in st and elsewhere, and should similar conditions become established ons now relatively inaccessible, the cutting cycle can and will be short- b coincide with these altered conditions.

creation or adoption of a relatively long cutting cycle as a basis of ion of these virgin forests is the only measure which permits of the working out of practical regulation under the conditions of transition s where it is now most urgently needed. But a cutting cycle equalling 4 to $\frac{1}{2}$ of the rotation will affect all the other elements entering into blem of regulating the cut. These elements are,

- The area to be cut during the cycle,
- The felling reserve,
- The minimum exploitable age,
- The growth available for cutting during the cycle,
- The volume of the total cut and of the annual cut,
- The "normal" growing stock.

se relations have apparently been overlooked in previous discussions ulation of American transition forests but their comprehension must e the formulation of any practical plan of regulation involving a long or transition-cutting cycle.

Similarity of Even-aged and Many-aged Forests. In order to make he influence of the cutting cycle upon these several factors, we must armonize the conception of a forest composed of even-aged, and one y-aged stands, termed frequently a selection forest. In theory, a forest n-aged stands may contain but a single series of age classes each com- of a single even-aged stand. But in practice, especially in forests where st silvicultural management has been applied, such a forest would be sed of many different series of age classes and of a much larger number atively smaller areas occupied by stands of even age. These separate s are intermingled but still exist as distinct areas. But in *cutting*, the ions will be spread in any year over a much wider general area to these patches than would be the case with a single series of age s; and within a single cutting cycle, logging operations would reach nd cut only the mature stands in each block or logging unit in the in succession.

s but one step further to carry the process of intermingling to areas s than an acre, or to the single tree or small group. The number of asses, their volume, and the total area occupied by each age class can be me,—the form and management only is different.

e two forms of forest are not identical from a silvicultural standpoint, the laws of tree growth differ specifically, but from the standpoint ulation and of the cutting cycle they may be considered as essentially ame.

117. Residual Growing Stock and Felling Reserve. Under the definition of a cutting cycle, no cutting (except thinnings) is done on an area between two successive major logging jobs or fellings which are separated by a period representing this cycle.

After each cutting, a residual stand is left on the logging unit, common in forests of even-aged stands of all the stands below the felling age, in forests of many-aged stands, of all stands below the felling size, i. e., small to cut under the limitations agreed upon as to size or age. This may be termed the *residual growing stock* (not to be confused with the term "residual growing stock" as commonly used to indicate a theoretical total growing stock required in a normal forest. Chapter VI.)

During the cutting cycle, the stands and trees constituting this residual stock are growing, and a certain proportion of the older stands in the even-aged form, and of the older trees in the many-aged form, grow into the younger and size classes suitable for cutting, after the area has been cut over and the timber cut. This portion of the growing stock is termed the *felling reserve*.

118. Illustration of a Transition Cutting Cycle in a Normal Forest. The influence of the cutting cycle upon the forest can best be brought out by an illustration. Let us assume that we have a forest of all ages ranging from one to fifty years, and that the trees of these age classes is scattered over the entire area of the forest and not grouped together, that in order to harvest each crop when it reaches fifty years of age, the entire forest would have to be gone over every year. But it is desired to concentrate operations on one-tenth of the area annually, with a cutting cycle of ten years, or $1/5 r$.

Let cc = cutting cycle of 10 years and r = rotation of 50 years.

The area of the forest can be assumed as 500 acres, divided into 10 blocks or units of 50 acres each. The amount of ripe timber to be harvested annually would occupy 10 acres all told.

To fulfil these conditions, this forest may have 500 separate even-aged stands of 1 acre each, ten of which fall in each age class, or, if it is of a typical many-aged forest, every acre will have trees of all of the 50 age classes present, but the aggregate area of each age class on the forest will be just 10 acres.

If regularly distributed, the even-aged form will have on each of the 10 fifty-acre blocks or annual cutting areas forming the 10 year cutting cycle, but 1 acre fully ripe in each block, while on the many-aged forest trees fully ripe are found on each of the 50 acre blocks, but their total volume is equivalent to but one acre of ripe timber in each block. To cut each stand or tree when ripe, in such a forest, would require cutting within every block, in every year, or a cutting cycle of 1 year.

Effect of Transition Cuttings on Forest. By contrast, in the first year of a ten-year cutting cycle the annual cut must be concentrated on one block of one-tenth of the total area or 50 acres and it must cover 10 acres instead of but 1 acre, in this block, and neglect the ripe timber in the other nine blocks for the present. To secure the same amount of timber, the first year's cut must include besides the one acre of ripe timber on this area, 9 acres more—and to do this we must cut timber down to 41 years of age. The age of the youngest timber cut would thus include stands down to the limit of $r - cc$ or 40 years.

But at the end of the second year, when cutting in the second block of 50 acres, it is not necessary to cut 41 year old timber. Each of the 10 acres to be cut is one year older, ranging from 42 to 51 years. Should the cut be made to include all timber in the block down to the same age or the same minimum size limit as in the first year, i. e., $r - cc$ years, 11 acres would be ready for cutting aged 41 to 52 years. This comparison can be traced through the 10 year cutting cycle. In the first case, when

are cut annually, the average age of the stands cut increases until at the end of the tenth year the cut is from 51 to 60 year old timber; 100 acres have been cut. The average age of the timber cut during the 10 years was, for the first year, 51 years, for the last year 55 years, and for the cycle 50, or r , years. This process can be repeated in five successive cycles until the entire forest of 500 acres is cut.

The effect of this cutting cycle on the form of the forest now becomes evident. If the action is by planting or occurs immediately, the forest in the fifty-first year will be composed of fifty instead of five hundred crops, each ten acres instead of one acre. On each block there are but five age classes, one for each 10-year cutting cycle. In this rotation the average period of growth, $\frac{1}{2}cc$ or 5 years marks the average variation in average age of annual cuttings from r or fifty years, but the average age of all cuttings is fifty years in the second rotation, each stand matures at r or fifty years, each is 10 acres in size and each can therefore be cut when ripe, when the cutting is now made on a ten-year cutting cycle.

Establishment of Minimum Exploitable Age. Thus the felling reserve originally contained all stands from 41 to 50 years old inclusive, but in the tenth year contains stands 50 years old, or stands from $r - cc$ to $r + cc$ years respectively. The cutting must evidently permit the removal of timber below r years in age in order to effect the transformation from a many-aged to a regulated forest. The age $r - cc$ or $r - 5$ is the *minimum exploitable age*, in this illustration, and is evidently affected by the length of the cutting cycle—the longer the cycle, the greater the inroads upon the forest not yet fully matured to the age of r years.

Transition between Rotation and Cutting Cycle. It is evident that as soon as the transition of form and arrangement of age classes is completed, the timber will be cut at the age r years which is the maximum age of the residual growing stock, plus the period of the cutting cycle, and equals the rotation. In this case, a transition of one perfectly normal forest to another is chosen for illustration, in which there was originally no overmature stock, and the only change made was a regrouping of age classes made necessary by the adoption of a 10 year instead of a 5 year cutting cycle.

The same principles apply to the transition of a virgin forest composed of timber of all ages, whether scattered as single trees, grouped in small patches, or assembled in larger areas. The rotation r will mark the average age at which the stands should be cut—but unless the minimum exploitable age is lower than this the timber even in the second cutting cycle will reach an average age greater than r years before it can be cut. The cutting creates, from this original forest, a forest moulded after the plan on which this cutting cycle is regulated.

The felling reserve is simply the upper portion of the growing stock. In a regulated forest none of it finally need be allowed to exceed the age of the rotation, although it did and must exceed it in part during the period of transition cuttings. The final result is, that the cutting cycle is merely the period of the rotation r , while timber both below and above r in age and size has been cut.

Ultimate Form of the Forest. The first ultimate effect of the cutting cycle, granting that reproduction is secured promptly, is then to modify the arrangement of age classes as to area and number to conform to the routine system of cutting of which the cycle is an application. There will be, ultimately, as many age classes on each area or logging unit as there are cutting cycles in a rotation. If the cycle is $\frac{1}{2}r$, the many-aged character of a stand

will tend to give place to two main age classes,—if $\frac{1}{3} r$, to three classes. The second ultimate effect, contingent on the first, is to produce crops which reach just the merchantable age desired, or r years, on successive areas of proper size, annually. A short cycle, adapted to the perpetuation of a regulated form of stand, permits numerous separate crops to originate on the area unit during the rotation. Under the moulding force of a consistent policy of regulation the plastic forest tends to assume the form which nearly fulfills the desired objectives.

120. Principle of Allotment of Definite Stands for Cutting During Period. But the *immediate* effect of the cutting cycle, for the first rotation, will depend upon the *method of its application*.

In the illustration given, the principle of regulation employed is the allotment of definite stands occupying a definite total area, for cutting during a given period. The cut for the period is the initial volume of these stands plus the growth for $\frac{1}{2} cc$ years. The fact that during the period young stands will mature to a minimum exploitable age over the whole area is ignored, although approximately half of this maturing volume will be in areas not yet reached in cutting, and this accretion of exploitable volume in such areas is wholly apart and in addition to the growth on the areas of stands allotted for cutting during the period.

If, in theory, *none* of these maturing stands are to be cut till the second period, then the cut is *in effect* as described by the first illustration, and the forest at the end of the first cutting cycle *in theory* has no regular establishment or felling series for the next cutting cycle, but is again covered by an equal number of stands of all ages in each cutting area. Only the reproduction during this period has been "regulated" to conform to the new cutting cycle, and will not be cut until the next rotation.

But *in practice* this is not the way it is done. The calculation of volume to be cut is a quantity check, leaving the areas or specific stands to be selected by the forester. He will take the oldest or those most in need of cutting. Allotment of specific stands long in advance of operations has lost favor in European practice where the effects of a cutting cycle are reduced to a minimum by shortening the cycle and going twice or three times over the area in an allotted period, e.g., for a period of 20 years, the cycle may be but 5 years in length, each area is cut 4 times within the period. Or the periodic allotment of areas is made moveable or progressive by the continuous addition of areas as others are cut over. (French *quartier bleu* method.)*

With short five to eight year cycles the difference in age between stands cut at r years, or at $r - cc$ or $r + cc$ years does not exceed the limits expected in the ordinary management of a regulated forest.

121. Principle of a Horizontal Cut to Fixed Limits of Age or Size. The *felling reserve*, or serial arrangement of the merchantable age classes, is usually created by cutting a forest once over during a cutting cycle, whether or not it is recognized in the plan of management.

But when as in the transition rotation for virgin forests, the rotation is to be fairly long to begin with, and the cutting cycle, being $\frac{1}{3} r$ or $\frac{1}{2} r$, is

* See page 239, *Studies in French Forestry*, John Wiley & Sons, New York.

between 40 and 100 years in length, the method of theoretical allotment of stands or age classes for removal during such a long cycle will differ so widely from the practical demands of regulation and of logging, that these discrepancies can no longer be concealed or ignored. The progress of the stands by growth and decadence goes on. In the logging of successive rotations, by the *theory of allotments* only the timber which had reached the minimum size agreed upon at the *beginning* of the period would be logged at the end of the period and this would mean, as in the illustration given, a constantly increasing age or diameter, but this time *over a long period*.

Instead, the *cut* will be forced to proceed along a horizontal line of cleavage, cutting from each successive area *not* merely the stands which *originally* were ready for cutting, but also those which have matured since and are ready for cutting when the area is to be cut over. By this method, a felling reserve is built up on the areas behind the saws, i.e., is created in the first cutting instead of at the end of the first rotation, for the reason that on areas cut by the saws all the newly maturing crops are cut along with the old stands. It is self-evident that if logging and silvicultural conditions actually demand the removal of a given per cent of the stand, they will continue to do so as long as the basic economic factors remain unchanged, after that the working plan itself must be revised.

Application of this Principle to Transition Cuttings. This working principle may be termed the *principle of a horizontal cut and felling reserve* as contrasted with that of specific allotment of stands. Taking the forest described in the first illustration, but applying this principle of cutting instead, the forest would be cut over by removing each year all the stands on each cutting area which are ready to cut, i.e., are forty ($r - cc$) years old, in order to create at the end of the first rotation a cutting series equivalent to a ten (cc) year cutting cycle.

Cut on Area and Volume to be Cut Annually. As one additional crop reaches the maximum exploitable age each year in each block, the cut at the end of the first year of this plan in the previously regulated or normal many-aged forest would cover 100 acres and for the twentieth year, twenty acres, while during the ten-year cycle, instead of 100 acres being cut, the area logged will be 150 acres. This method not only decreases the area cut in the first period by fifty per cent but increases the volume cut somewhat smaller per cent. (The young maturing stands have ten years less age than those originally in this period, hence a smaller volume.) The process would remove all of any surplus stock during the first cutting cycle. This surplus stock consists of the stands which must grow to a maximum age of $r + cc$ years (60 years), before being reached in logging, the actual ages of these overmature stands falling between r and $r + cc$ years (51 to 60 years). The effect of the horizontal cut would be to reduce the growing stock below normal, and prevent any stand in the future from growing to an age exceeding r years, as long as the plan is adhered to. During this first cutting cycle, the advancing age of the surplus would raise the minimum age of the stands cut, from $45(r - \frac{1}{2}cc)$ to a final 50 (r) years in the last year of the cycle.

At the end of each cutting cycle *after* the surplus is removed, during the first rotation, the minimum age of the stands cut will be $r - \frac{1}{2}cc$ or 45 years, after which the normal management being secured, the stands during the second rotation may be cut at r or 50 years.

Application of These Two Principles in Contracts for Purchase of Timber Cutting Rights. The distinction between these two methods of regulation may be

further illustrated by citing certain timber sale contracts for the purchase of standing timber for cutting. In these contracts a diameter limit is usually specified, a period fixed within which all timber so purchased must be removed. Numerous suits have resulted from failure to recognize the fact that trees grow in sized stands, the owner who sells would favor the allotment method of cutting described above, which none but the trees which were of the stipulated size of age classes at the time of sale could be cut within the period. This would coincide with the first illustration, the purchaser would get the growth on the allotted stands but no new or mature stands.

The purchaser, however, insists that he is entitled to a horizontal cut of all timber which is of the specified diameter at the time he reaches the area in question, claiming that it is utterly impractical to distinguish from year to year, in cutting, the trees which were below the given sizes in the first year of the cycle and that nothing was said about this anyway in the contract. If permitted, he therefore cuts on the plan described in the second illustration leaving only the timber which matures behind the saw, the so-called felling reserve. If the contract is so loosely drawn as to permit him to cut the same area over more than once, i.e., cut in two cutting cycles, he can of course begin where he left off and cut the felling reserve, continuing this process indefinitely as long as his contract permits him to cut. The Carr contract for the sale of timber on the former Vanderbilt holdings, now the Pisgah National Forest was let on this basis, and has resulted in great embarrassment to the government. It would be as well for owners of timber to recognize sooner or later that trees grow in sized stands, their indifference to forestry. The basis of a straight or horizontal cut is the most practical basis of a contract for cutting, but the payment should not be in a lump sum at time of sale,—rather, on the basis of scaled cut and with provisions for adjustment in rates on a long period, with confinement of the cut to one cutting cycle, or more, over the area.

123. Effect of a Surplus of Overmature Timber upon the Minimum Exploitable Age

While in large areas the original growth may resemble the normal forest of the first illustration in having no regularly arranged felling reserve but rather, a distribution of all age classes over the entire area, yet their chief characteristic is an excessive surplus of growing stock when measured by empirical normality (§65). When, even on an empirical basis, the forest, because of past fires and abuse has less than the normal quantity of overmature and ripe timber, yet it is sure to have stands whose age greatly exceeds that of any reasonable rotation for future management.

This surplus, or in its absence, the excess in age of the mature stands, makes unnecessary in regulation to draw on stands as young as $r - cc$ years to make up the cut for the first cycle. If on account of good transportation the cycle can be shortened and the annual cut distributed correspondingly on a larger gross area, the cut for the first or even the first two cycles, depending on length of cycle and conditions, the quantity of overmature stands, may be confined entirely to trees which are older than r years. This postpones the reduction of the surplus over a corresponding period.

But with a long cutting cycle, the lack of properly arranged cutting series in the forest and the necessity of a heavy cut per acre will compel the cutting of trees less than r years old in the first cycle, until this series is established. It will not be necessary to cut trees $r - cc$ years of age, however, because of the existence of this surplus whose tendency is to supply sufficient timber of a larger age, i.e., to raise the minimum exploitable age. This might be set, for instance, at $r - \frac{1}{2}cc$ years instead of $r - cc$ years.

This process contains the key to the regulation of the cut in transition forests in order to equalize the yield during the cutting cycles in which the surplus is being disposed of. The greater the surplus, and the shorter the cycle, the nearer can the minimum exploitable age coincide with the rotation age r . Conversely, with a longer cycle, the higher this minimum age or size is placed, and the nearer it coincides with r years, the more timber will be left per acre, the more surplus will be carried over to the second cutting cycle and the more the cut will be evened off as between successive cycles while the surplus is being removed.

Desirability of Short Cutting Cycles when Possible. It is evident from the standpoint of the forest, in order to reduce waste from over-rotation, carry over and distribute the surplus, break up the cutting areas into smaller units and reduce the volume required in the felling series to a manageable factor, a short cutting cycle is indicated for transition cutting, and only the necessity of harmonizing the methods of regulation with unavoidable economic factors (§III) will force us to adopt long cutting cycles for present on some of our forests.*

With the short cutting cycle the allotment principle can be adopted (first rotation §II5-II6) as the basis of calculating the cut, especially in forests that have already been partly or entirely cut over and now consist of culled stands and second growth, with small residual tracts of original growth—many of our national forests in the Appalachians and White Mountains.

Necessity for Horizontal Cut and Long Cutting Cycles on Virgin Forests. But where economic conditions require a long cutting cycle for transition of a large area of original and overmature forest, the actual difference between the required standard of cutting in logging operations and a theoretical allotment of definite stands or size classes becomes great to be ignored, and the allotment of cutting areas and calculation of annual cut must be made to conform with these conditions. The cut must be determined or limited on the basis either of area, or volume, or rotation.

Apparently in the transition of a forest already normal, as in the first rotation (§II6), this method of horizontal cut would increase both the area cut over and the volume removed in the first cutting cycle to an excessive amount and be no better than the allotment plan in its ultimate effect.

But we are not dealing with a normal forest. The two practical considerations which we face are the surplus in overmature age classes, and the waste and loss occurring in these classes.

As seen, the surplus tends to raise the minimum exploitable age, hence gives one objection to the horizontal cut, that of lowering the average age of cutting.

Determining Influence of Factor of Decadence. But the real factor is the loss from decadence. A certain portion of the volume of overmature timber annually dies or is killed or destroyed annually in such forests. This reduces the area occupied by the merchantable stands, and the available volume that can be cut during the cycle. If we falsely assume that this loss does not occur, and proceed on the allotment principle in fact, by progressively increasing the age or diameter limits during the cycle (§II5-II6), both the

the cutting cycle on the western yellow pine type in Arizona and New Mexico unconsciously lengthened from about 60 or 70 to 100 years by a change in the rate of marking, which removed a greater per cent of the mature yellow pine timber, increased the cut per acre and, as applied in practice, lowered the average minimum exploitable age to between $r - \frac{3}{4}cc$, and $r - cc$ years by heavy marking in Blackjack classes. The reasons for this change were the absence of silvicultural necessity in leaving $\frac{1}{3}$ of the stand, the favorable effect on stumpage prices of increasing the yield per acre, and the avoidance of loss in leaving large valuable timber at time of first cut. There was also in many stands the necessity of cutting heavily to wipe out loss from mistletoe and disease.

volume available for cutting and the area occupied by the assigned stand will diminish to the extent of this decadence, which in a cycle of $\frac{1}{3}$ of the total available cut (25 per cent is unreasonable).

This unavoidable loss is accompanied by a natural reproduction which will be available in the next rotation, but not in the present one. For this reason, not only because of practical economic conditions of logging, but in order to apply common sense in regulating the cut and renewing the forest, *age and size classes which mature ahead of the saws during the first cutting cycle must be included in the cut for that cycle*, by adopting the principle of a horizontal cut and felling reserve in regulation.

126. Illustration of Application of Principles to Western Yellow Pine. To illustrate the effect of this principle upon transition forests we will assume a rotation of one hundred years for western yellow pine, and a cut of eighty per cent of the merchantable volume. This cut is heavier than will be necessary in the second cutting cycle and constitutes a larger per cent of the stand, because of the surplus of overmature timber in the present and resultant deficit of younger age classes. The growth predicted on the remaining stand indicates a period of one hundred years as required to produce, in the twenty per cent of merchantable timber plus the maturing of young stock, a volume of sufficient volume per acre to justify logging operations similar in character to the original operations and the logging of timber which would otherwise be rendered inaccessible. The cutting cycle is then fixed at one hundred years or $\frac{1}{2}$ r. On an area of 1,000,000 acres, the annual cutting area will be 10,000 acres. But on this area the cut actually covers but one half for the other half is occupied by young timber and reproduction. Actually then, 5,000 acres of mature timber is cut annually, and in one hundred years the tract is gone over twice but each acre of ground is logged only once.

The average age desired is 200 or r years. If this forest were a typical many-aged forest, and no overmature timber existed, the maximum age of the standing timber would at the start be 200 years, ranging down to 1 year, with an average age for the stands, of 100 years or $\frac{1}{2}$ r.

But the actual age of the overmature timber is 300 years, and the average age of the stands is nearer 200 than 100 years.

If the cut is determined on the allotment principle, the volume of the annual cut will be the present volume of the stands which constitute eighty per cent of the volume of merchantable timber, plus the net growth for one hundred years, on the age classes which make up this eighty per cent.

The timber lost by decadence in overmature stands must be deducted from the available cut. The area reproduced, as the *combined result of cutting and of replacement following natural losses* in the stands, will or should be about one half the total area, 5,000 acres per year.

Effect of Substitution of Horizontal Principle. But if, in logging, the same diameter age limitations are applied to the cut each year, and the principle of a horizontal cut is adopted, the following conditions are faced:

1. If the total loss by decadence has been calculated and deducted from the available cut, the limitation of the annual cut will be correspondingly reduced by the amount of this loss. Now, unless the cut is actually confined to the allotted age class (if instead) the younger timber maturing ahead of the saws is cut as logging operations reach the areas, the additional volume thus available per acre slows up the progress of cutting if limited as above, and the failure to coördinate the calculated cut with the operating conditions will result in a failure to complete the removal of the old timber in the desired cutting cycle.

2. If on the other hand the amount of timber maturing ahead of the saws has

calculated, and included in the possible total cut, the annual cut as calculated agree with the volume which will be available, and the cycle will see the removal of overmature timber as planned.

Under the other plan, because the actual cut is on the horizontal principle, a felling reserve of a cutting series of graduated age classes will be built up behind the saws, the timber left standing, but in the latter case it will be of the required arrangement with a maximum age equal to the minimum exploitable age plus cc years and including cc age classes.

It is not necessary, in the first cut, to remove from this forest in the first cycle all timber down to $\frac{1}{2}r$ years in age, i.e., to 100 years. The preponderance of overmature timber may be such that the minimum exploitable age may be set instead, at $\frac{3}{4}r$. The cutting cycle will take care of this surplus which is carried over.

In illustration, assume that the average age of the timber to be cut is 250 years and the minimum exploitable age of 150 years or fifty ($\frac{1}{2}r = cc$) years less than r years. If the principle of allotment is applied, the average age of the stands cut during the cutting cycle would finally, in the last year, reach to 350 years, and the average age for the whole period or cycle would be 300 or $r + cc$ years, with a constant serious loss of timber by decadence for 100 years.

We now include the additional areas which will mature ahead of the saws, during the cutting cycle of 100 years, this should amount to one half of the timber now standing on 150 (minimum exploitable age) and 50 years of age.

By giving the area of this young timber, this quantity can be obtained. If for example, two thirds of the area of young timber below 150 years is from 50 to 150 years of age, and the sum of these young age classes covers half the total area, then 166,666 acres will mature in 100 years, one half of which will be on areas ahead of the saws and one half on areas behind the saws or on areas already cut over. Then 166,666 acres of young timber should be cut and reproduced in the cutting cycle of $\frac{1}{2}r$ years. This increases the area of the annual cut by $33\frac{1}{3}$ per cent. The increase in volume depends upon the rate of growth of the stands, and should be calculated from yield tables, as was done for the old timber. The total cut would be materially increased, the annual limitation of cut correspondingly increased, the decadent timber all removed in 100 years, the surplus largely reduced and a felling reserve created containing timber 150 to 250 years old. On the other hand, if the allotment idea is theoretically held that the 150 year old timber standing on the *last cutting area* would not be cut in 100 years when it was 250 years old but would go over into the second cycle and reach a considerably greater age before cutting.

Sum up:

The presence of a surplus of overmature stock enables a transition cutting to be carried out with a minimum exploitable age higher than $r - cc$ years. But if the allotment principle of calculating the annual cut is applied, this in itself results in slowing down the cut and holding over the standing timber to a greater average age. Therefore the minimum exploitable age is best calculated when the annual cut is made to include the timber reaching this minimum age during the period.

7. Basis of Computing the Annual Cut by the Principle of a Horizontal

Summary of Previous Conclusions. It has been shown that the cutting cycle is merely the last period in the rotation coinciding with the period between the minimum exploitable age and the normal age of cutting; that the transition cutting, either from one normal forest to another, or from an unregulated forest to a regulated form, a rearrangement of age classes takes place, creating a felling reserve for the succeeding cutting cycle; that this felling reserve is the apex of the triangle or final group (see fig. 6) of the complete series of age classes required by a normal forest; that in the last period, the presence of a surplus enables the transition cutting to take

place by placing the minimum exploitable age at $r - \frac{1}{2}cc$ years, and to secure an average of r years or over; and that after regulation, the cut age of all stands cut can be r years.

Relations of Growth to Cut in Normal Forest. The calculation of the possible cut for the cutting cycle is based on very simple principles which run directly to the desired normal series of age classes created by progressive cutting. These are,

1. *a.* The cut from a normal forest for the rotation is just equal to total growth during the rotation.

b. If the growth is (incorrectly) assumed to be laid on in equal amounts, then the growing stock required to maintain an annual cut is $\frac{1}{2}$ of the total growth or of the total cut for the rotation.

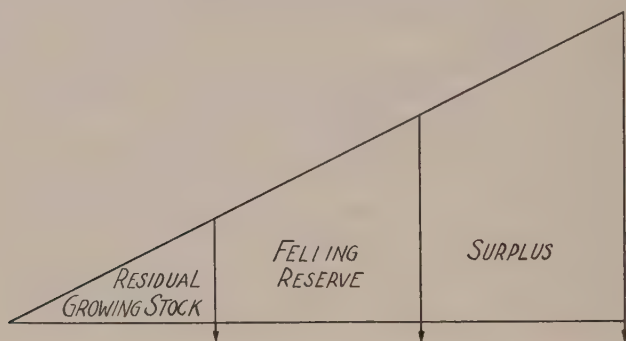


FIG. 6.—Illustration of Residual Growing Stock, Felling Reserve and Surplus.

c. The average age of this growing stock at any time is $\frac{1}{2}r$ years.

d. The period which the average stand will remain before being cut is $\frac{1}{2}r$ years. The growth put on is the growth for $\frac{1}{2}r$ years. The cutting period is r years.

Analogy with any Lesser Period as a Cutting Cycle. Allotment of Timber Now Mature.

2. These same relations hold good for any lesser cutting period, such as a cutting cycle, as follows:

a. The timber which may be cut during a cutting cycle under an allotment plan, consists of all the timber now above the minimum exploitable age or size. This constitutes in an unregulated forest, the felling reserve plus the surplus.

b. The timber below this age, or residual growing stock, coincides with the age classes of a normal forest below the minimum exploitable age. This division may be indicated as follows:

c. During the cutting cycle, the stands allotted for cutting, i.e., those that are ripe at the beginning of the cycle, will be cut progressively, so that the average period elapsing before cutting is $\frac{1}{2}cc$ years.

d. The average growth put on by these stands is therefore equal to

growth for $\frac{1}{2}$ cc years, or $\frac{1}{2}$ the growth for cc years, which is not the thing. These two ways of expressing the growth are more nearly the same for any period or cutting cycle of less than r years than for the rotation period. There is not so much diversion between current and mean annual growth in the shorter period. The latter method of calculation can therefore be adopted, and is universally used in European regulation to determine the growth available for cutting.

e. The total volume available for cutting from stands allotted to the cutting cycle at the beginning of the period is then

Volume + Growth for $\frac{1}{2}$ cc years.

In practical operations, on a large area and with a fairly long cutting cycle, all trees which reach the minimum size or age during the cycle, and stands which have not yet been reached by the progressive cutting operation, will be cut with the remaining mature stand which constituted the residual volume above this size or age.

If it were possible to cut all the mature stock above the exploitable age at *half the cycle*, the growth realized on this stock before cutting would be of $\frac{1}{2}$ of the total growth, or $\frac{1}{4}$; $\frac{1}{2}$ because of the reduction in length of the cutting period, and only $\frac{1}{2}$ of this because of the serial progression of cutting which reduces the period elapsing before cutting to half of the rotation period. Again, if the maturing stands could all be cut in the last half of the cycle, the growth on these stands would be $\frac{1}{2}$ plus $\frac{1}{4}$, the first because no cutting occurs for half the period and the remaining $\frac{1}{4}$ th because of the serial progression of cutting. Thus the sum of the growth realized on both classes is roughly $\frac{1}{2}$ of that on all stands cut.

Because of the fact that both the mature and the maturing stands are cut simultaneously throughout the *period*, the growth realized on the mature stands instead of being $\frac{1}{4}$ th will be $\frac{1}{2}$ of the total, while that on the maturing stands will be *less than* $\frac{3}{4}$ ths and will more nearly approximate $\frac{1}{2}$. Actually, it will slightly exceed $\frac{1}{2}$ in a forest of all ages, since even with progressive cutting, the larger portion of the maturing stands will mature in the latter half of the period. Therefore the assumption that $\frac{1}{2}$ of the growth on stands to be cut is conservative and practical.

In fixing the minimum exploitable age at $r - \frac{1}{2}$ cc years, the stands which reach this exploitable age in cc years will be all those ranging from $\frac{1}{2}$ cc to $r - 1\frac{1}{2}$ cc years at present. Of those stands, a volume equal to $\frac{1}{2}$ the total, or approximating those now $r - \frac{1}{2}$ cc to $r - cc$ years will be cut, plus $\frac{1}{2}$ the growth on these stands. The remainder will constitute the felling reserve for the next cycle.

The cut for the first cycle can then be recast as follows:

Volume of all stands above r years plus $\frac{1}{2}$ growth for cycle.

Volume of all stands from r to $r - cc$ years plus $\frac{1}{2}$ growth for cycle.

or,

Volume of all age classes down to $r - cc$ years, plus $\frac{1}{2}$ growth for cycle.

It is thus seen that the one essential step in securing a horizontal cut, in calculating the volume and increment of the stands to be cut, is to fix the minimum exploitable age at $r - \frac{1}{2}$ cc years, which step will permit

of the formation of a felling series and felling reserve during the first whose average age is $r - \frac{1}{2}cc$ years, and whose age, when cut, will be age r years.

The cut for each progressive cycle will then equal the volume of all above $r - cc$ years at the beginning of the cycle plus $\frac{1}{2}$ the growth for the cycle, the minimum exploitable age being retained at $r - \frac{1}{2}cc$ years, the forest has been completely cut over, which will require a full rotation.

128. Quiz. What three preliminary conditions are required to permit of undisturbed sustained yield management?

How does the character of our forests make regulation difficult?

What is the cause of overcutting?

What classes of growth data are required?

What classes of owners should practice sustained yield?

What cutting policy is indicated for other classes of owners?

What is the danger in such a policy?

How is this danger to be avoided?

Contrast sustained yield, destructive lumbering, and preservation of forest destruction as goals for private management; and for public management.

What is the effect of costs of logging on the required initial cut per acre?

How do the demands of silviculture influence the initial cuts?

Define the term cutting cycle.

What three factors determine the length of a cutting cycle?

What bearing has growth on cutover land and growth on virgin forests, respectively on the length of cutting cycles, and amount of the annual cut?

How does the cutting cycle differ from the rotation?

What is the relation between the cutting cycle and the cut per acre?

What element of forest regulation is affected by the length of a cutting cycle?

Describe the differences and similarities of forests composed of even-aged and mixed-aged stands.

Define the terms residual growing stock, and felling reserve.

Compare a normal forest of even-aged stands with one composed of many mixed-aged stands.

Describe the effect of cutting these forests on a 10-year cutting cycle.

Define the term, minimum exploitable age.

What is the relation between the cutting cycle, the rotation, and the minimum exploitable age?

How will the ultimate form of a forest be determined by the cutting cycle?

How is the theory of the allotment method departed from in practice?

Describe the principle of cutting termed the horizontal cut, and its effect in creating a felling reserve.

What effect does it have on the surplus, normal growing stock, and average age of cutting?

How are the allotment principles and those of the horizontal cut illustrated in tracts for the purchase of timber stumpage for future cutting?

Describe the effects of surplus of over-matured timber on the determination of minimum exploitable age.

How can this surplus be thus distributed in point of time?

What factors indicate a choice of short cutting cycles in virgin forests?

Why do long cutting cycles require a horizontal cut?

What effect has the factor of decadence in virgin forests favoring the adoption of horizontal cuts?

CHAPTER XI

APPLICATION OF REGULATION TO AMERICAN FORESTS

Resumé of Principles. 1. The management of American forests be based primarily on protecting and continuing the productiveness of land, and in this form it is applicable to all classes of owners.

The regulation of the annual cut to attain a sustained yield is not possible and can be attained only when both the economic and physical conditions are favorable.

Market conditions and the cost of transportation and logging as reflected in stumpage prices, combined with the silvicultural demands of type and species as influencing reproduction and health of the stand, will determine the character and per cent of the initial cutting per acre, and cannot be radically modified.

The per cent of the stand which is cut and the resultant rate of growth of the cutover lands, taken in connection with the future conditions of logging and transportation, will determine the period which must elapse before the second cut. This period is the cutting cycle.

The total available cut of mature timber as determined by the area, per acre to be cut, and growth available before cutting on these stands, indicate the limitation of the annual cut required in order to secure a sustained yield.

The same basic principles of regulation apply to forests of all forms, whether even-aged or many-aged.

Wherever transportation conditions make forests readily accessible to active markets, short cutting cycles are adopted, and the principle of regulation most frequently employed is that of allotting a definite per cent of mature timber by volume and by area, to be cut during the cycle.

When, because of difficult transportation problems, forests are relatively inaccessible and a long cutting cycle must be adopted, the principle of horizontal or progressive cut which coincides with the method of cutting actually applied on such forests must become the basis of calculating the amount of the annual cut and regulation of yield.

This principle recognizes the fact that the cutting on successive areas must continue to require the same age and diameter limits as originally agreed upon, regardless of the growth and change taking place in the forest.

This means the inclusion in the cut of all stands which reach the maximum exploitable age ahead of cutting on the specific areas.

The apparent excess of cut which would result, both by area and volume, in this enlargement of the cutting areas allotted for the period is offset, for unregulated original growth, by the unavoidable decadence and death of a per cent of the stands, and by the resultant natural reproduction, which factors reduce the area actually cut over.

The regulation of unregulated forests is a transition resembling in

character the transformation of a regulated or normal forest from one or grouping of age classes to a different form, such as would be made necessary by a change in the length of the cutting cycle.

13. *The ultimate form and arrangement of the age classes in any form is the direct result of the cutting cycle adopted.*

14. *The period represented by the cutting cycle is not an addition to the rotation, but is the last period in the rotation.*

15. The transition cuttings under a given cutting cycle require the cutting of stands of less than rotation age, to a minimum age of $r - \frac{1}{2}cc$ years, and require the holding of other stands to an age exceeding the rotation maximum of $\frac{1}{2}cc$ years, even in a normal or regulated many-aged forest.

16. The same range of ages for cutting is required in transition cutting in an unregulated forest,—but in forests possessing a surplus of overmature timber, the minimum exploitable age in the first cutting cycle can be higher, if desired, in order to conserve the surplus and prolong sustained yield.

17. In either case the minimum exploitable age during this cycle shows just $\frac{1}{2}cc$ years less than the average age of the timber to be cut.

18. The adoption of the principle of a horizontal cut in the first cutting cycle establishes in that cycle a cutting series constituting a felling reserve for the succeeding cycle, consisting of a series of age classes whose number equals cc years and whose individual areas equal the annual cutting area.

19. This felling reserve is created by the growth of the timber below the minimum exploitable age (size) constituting the residual growing stock, which growth causes this timber to mature or enter the exploitable age or classes.

20. The cut for the first cycle comprises the timber above the exploitable age plus half the growth on the entire forest during the period.

21. The portion of the cut representing growth is made up from $\frac{1}{2}$ the growth on the above merchantable timber plus $\frac{1}{2}$ of the total remaining growth on the entire forest.

22. This latter quantity is equivalent to $\frac{1}{2}$ of the volume of stands entering the exploitable class and $\frac{1}{2}$ of the growth for the period on these stands plus the volume of all stands between r and $r - \frac{1}{2}cc$ years plus $\frac{1}{2}$ their growth.

23. Although the volume of stands entering the exploitable class during the period is equivalent to the growth for the period on all the remaining young stands in a normal forest, this is not true of an abnormal forest, with an irregular distribution of age classes, and statement 20 must be modified by substituting statement 21 and 22, for the expression, $\frac{1}{2}$ the growth on the entire forest for the period.

24. For all forms of forest, regular or irregular, the cut for any cycle is equal to,

a. The timber above the exploitable age,

b. Plus all the volume occurring either as growth on this timber or in the form of maturing timber entering the merchantable age classes before they are cut over.

25. The volume and growth on timber entering the merchantable age class (above the minimum exploitable age) after the areas are cut over plus

and growth which will mature before cutting, in the next cycle, will form a forest about equal the volume and growth cut during the cycle, and will constitute the next felling reserve for the succeeding cycle.

The adjustment of annual cut over 2 or more cutting cycles to create a surplus, in transition cuttings, depends on the possibility of changing the cutting cycle, raising the minimum exploitable age and diminishing the per cent of the cut per acre in the first cutting.

Actual logging operations in all classes, types and forms of forests in America will be governed by these principles no matter what theoretical basis is used to determine the annual limitation of cutting. The *cut per acre* is the starting point, the recovery by growth will fix the *desired* period of the first cycle. Whether or not the forest is actually regulated for sustained yield will then depend upon the ability of the forester to limit the cut so as to bridge the gap. Only when the *total annual cut*, as determined by the *area cut annually from the working unit, as well as the cut per acre*, is reduced to the indicated quantity, can a sustained annual yield be secured. But if the silvicultural limit has not been exceeded in the cut per acre, protection given, and reproduction secured, then continued production is assured on the basis not of sustained annual, but intermittent periodic cutting which in the long run will produce fully as large a total yield of wood. When the productiveness or reproductive capacity of the forest is injured or impaired its ultimate total yield is reduced or destroyed.

The question as to whether a given forest unit shall be cut so as to bridge the existing stock in such a way as to produce from now on a sustained annual cut and revenue, instead of a much larger cut during a short period followed by a cessation of cutting until the forest recuperates, is the gist of forest regulation and must be determined for private forests by self interest, while for public forests, public benefits will clearly prevail to a sustained yield where the economic factors permit it.

Application of these Principles to American Forests. The conception that forests of even-aged and of many-aged stands are affected in the same manner by the above laws of cutting and growth, in the establishment of cutting series and felling reserves, simplifies the consideration of the application of these principles to American forests.

Preliminary Cutting Cycles for Valuable Species in Mixed Forests. Cases where originally a single species is merchantable in a mixed stand, make almost inevitable that later on the remaining species will become merchantable. In this case, the *growth* required will be the economic growth of the merchantable species and stumpage values. The first cutting cycle can not be based solely on the period required to produce an equal yield of the given species, for the chances are that this single species, as the result of cutting in a mixed stand, *will decrease in numbers and growth by suppression*. The cutting cycle must be based on the combined factors of growth of the species in question and the future merchantability of the remaining species. The total growth of the stand, not that of a fraction of it, is the only safe basis of regulation. Preliminary cutting cycles based on selection of species in mixed forests are *strictly preliminary in character, rather than transitional, since an abundant volume of*

virgin timber is left whose later transitional regulation constitutes the problem. This problem is quite common in tropical forests.

Since the development of the market cannot be predicted, and the cutting of valuable species might lead to their serious reduction or extinction,* the possible future growth of the residual stock of the expected species after cutting, and the period which would be required to obtain an equal cut of the species in the future might be used as a guide for determining the total cut, which could then be regulated to extend over this period. A sustained yield of the species is to be attempted. This principle of regulation was admirably brought out by Pinchot and Graves in the "Adirondack Spruce" (Gifford Pinchot 1898), for the Nehasane Forest, N. Y., although later research shows that the rate of growth after cutting fell short of the predictions on account of the severe competition of the hardwoods in the mill. The original cut of spruce which was completed in a very short period was intermittent rather than sustained since the desired concentration of the annual cut required this and the overhead cost for a smaller annual output would have made the extension of the cut over the period 1896-1900 unprofitable.

132. Transition Cutting Cycle. Example of Intermittent Yields in Private Management. The real transitional cutting on this tract is now taking place. Now the problem is, to determine how long it will take to clear the residual forest, cut for hardwoods and spruce, to recover so as to produce a yield which would justify a third cut whose volume will approximate the average productiveness of the forest. This tract is in the hands of an owner who is independent of the necessity of sustained yield, and no effort is now made to find out what this cutting cycle should be, but the tract is now logged over on a cycle evidently much shorter than would be required to sustain the cut, much as a lumberman would operate. To reduce this transition to a regulated annual cut and income, the rates of growth must be determined for hardwood stands left in the condition of these cutover areas. Such data are not at present available. But if the proper per cent per cent of the stand is being cut to secure the best growth and reproduction, criticism can be made of the operation only on the basis of the scheme of regulation adopted, and *regulation for sustained annual yield in this second cutting cycle optional with the owner just as it was in the initial cutting cycle for spruce.*

Under government ownership, the first step now, after fixing the limit of cut per acre and the species to cut and products to sell, would be to find out at once what is going to happen on that land, *before contracting for the sale of so much timber that the length of the period to complete the first cutting is already determined by the amount of the annual cut and sustained yield rendered impossible.* The amount to cut must be fixed by the period, volume available and growth, or the cut will be intermittent.

Regulation, therefore, presupposes some definite knowledge of *growth of stands and areas, not merely of single trees,** growth of average stands.*

* As a result of cutting and of fire protection, teak is not maintaining itself in Indian forests.

** See Forest Mensuration, pages 315 to 455, H. H. Chapman, John Wiley & Sons, 1921.

of normal or selected fully stocked stands, and growth of cutover, not merely of stands in the original forest. This knowledge can be used, and to try to regulate the forest without it is a poor makeshift, not so bad as failure to regulate it at all.

Assumption that Growth Balances Decadence. The previous discussion has shown that the straight allotment plan of regulation of the cut gives too small a cut if the loss from decadence of the timber is known properly deducted, and that to offset this factor the volume entering exploitable class by growth is included in the cut, by including the volume of trees falling in an additional class equal to $\frac{1}{2}$ cc years.

The determination of loss from decadence is admittedly difficult. Few successful attempts have been made to measure it though it is possible to

Owing directly to this fact, such efforts as have been made so far determine the total available cut for the first cycle in a transition forest usually been based on the balancing of one error against another. This is the assumption that growth in such virgin stands exactly balances loss from decadence and that therefore there will be no net change in volume of timber above the exploitable age on the average acre during the cutting

This conclusion is probably a conservative one, since to offset the loss on present timber we have not only the net growth on the age classes already mature or ready for cutting, but will add to this the volume and growth of the half of the maturing age class as well. The trouble is, that it *may be conservative, and fail to indicate the true amount of the available cut.* For a preliminary period of cutting, and for forests where the market or possible yield is probably below the permissible cut, this assumption might be as safe as any other since there is no danger of overcutting. If the rate of growth ascertained on cutover areas has indicated a cutting cycle of r years, the cut per year would then be x per cent (the cutting per cent) of the total merchantable stand above the exploitable age or size, divided by $\frac{1}{2} r$ years. Since the Von Mantel formula calls for a cut equal to $\frac{\text{merchantable volume}}{\frac{1}{2} r}$

the above result would be more conservative than that obtained by this formula for an equal cutting cycle. If the cutting cycle were found to be $\frac{1}{3} r$ or $\frac{1}{4} r$ years the cut per year would be decreased proportionately. But the crude Von Mantel's or the Austrian formulae both based on this assumption in that both take for granted that the forest is under management, has no decadent stock and is therefore *replacing the decadent stock rapidly by growth*, and for this reason, that the *entire* present stock can be removed in $\frac{1}{2} r$ years or less, without depleting the forest materially. With an absolutely stagnant stock, only the fact of overmature and excessive volume, and the desire to rapidly replace this stock with a young growing stock, would justify such an assumption.

4. Formula for Regulation of Cut Based on this Assumption. This formula for the annual cut may be expressed as

$$\text{Annual cut} = \frac{x\% \text{ of merchantable volume}}{\text{cc}} = \frac{\text{exploitable volume}}{\text{cutting cycle}}$$

The basis thus indicated becomes safer, the shorter the cutting cycle is and the smaller the per cent that is taken, since the x per cent then is more nearly to age classes on which decadence and growth for the period is apt to balance. This idea is practically the same as that of the French method of 1883, in which the cutting cycle, *based on growth*, was first fixed at $\frac{1}{3} r$, the exploitable age at $\frac{2}{3} r$ and the per cent to cut at $\frac{5}{8}$ or $\frac{1}{2}$ of the merchantable stand. (§ 87)

Then if G_a = Merchantable growing stock

$$\text{Annual cut} = \frac{.625 G_a}{\frac{1}{3} r}$$

The later addition by the French of growth of the veteran stands to cutting, to obtain the total permissible cut, is an attempt to get closer to the actual cut by studying the growth of mature age classes.

135. Illustration—Coconino National Forest. The application of this method in comparison with other formula methods, to the actual conditions on the Coconino National Forest, Arizona will bring out its characteristics.

Merchantable growing stock 3,151,147 M ft.

Area, 554,560 acres. Species, Western Yellow Pine.

Area cut over, 116,137 acres.

Net area of original forest 438,423 acres.

Average stand, on uncut area, 7,194 bd. ft.

Based on conditions of accessibility, and the silvicultural demands of the species and upon the measured results of past cuttings, the per cent of the stand to be cut is fixed at 80%.

Based on the average yields per acre, and the products desired, the rotation is fixed at 200 years.

Based on the rate of growth of the stands left on cutover lands,* and the growth required per acre to justify a second cut, the cutting cycle is fixed at $\frac{1}{2} r$ or 100 years.

Assuming no further knowledge of the composition of the stand, or the growth of the original forest, the cut will be,

$$\begin{aligned} \text{By the formula, Annual Cut} &= \frac{X\% G_a}{cc} \\ \text{Annual Cut} &= \frac{.80 (3,151,147 M)}{100} \\ &= 25,249 M \end{aligned}$$

136. Comparison with Von Mantel's Formula. Von Mantel's formula is based on the theory, not that there is no growth on the mature stand, but that this stand is growing and will be cut and replaced by growth, and that it now constitutes a serially arranged felling reserve. Since the relation between growth and growing stock on such a forest are,

Growth in r years = Cut in r years

Merchantable stock = $\frac{1}{2}$ Growth or $\frac{1}{2}$ Cut in r years

the cut per year on this forest would be

$$\begin{aligned} \text{Annual Cut} &= \frac{G_a}{\frac{1}{2} r} \\ &= \frac{3,151,147 M}{100} \\ &= 31,511 M \text{ ft.} \end{aligned}$$

* This rate was conservatively set at the rate realized on the original stand. Further study may indicate a dependable increase in growth after cutting.

comparison indicates that it is unsafe to neglect the factor of growth mature timber, or of the volume added by maturing stands, in a long cycle.

Effect of Shortening the Cutting Cycle. The effect of shortening the cycle, upon increased rate of growth after logging, or upon decision to require a certain stand per acre in the future as the basis of continuous cutting, is shown in the above case as follows:

$$cc = \frac{1}{3} r = 67 \text{ years}$$

$$\begin{aligned} \text{Annual cut} &= \frac{.80 \times 3151147 \text{ M}}{67} \\ &= 37,685 \text{ M} \end{aligned}$$

exceeds the cut by Von Mantel's formula, while if $\frac{1}{4} r$ or fifty years were used, the cut would be

$$\begin{aligned} \text{Annual cut} &= \frac{.80 \times 3151147 \text{ M}}{50} \\ &= 50,498 \text{ M.} \end{aligned}$$

by shifting the *length of period* over which the present merchantable stock is to be spread, the annual cut obtained in the first cutting cycle can be readily modified. The determination of the amount of cut which the forest will yield annually without overcutting, and which will bridge the gap between the first and second cutting cycles so as to actually produce a sustained yield, is not a question of formulae or mathematics at all but an attempt to estimate the results of living forces over a long future period. On the soundness of the observations and measurements of growth on which we make our prediction will rest the success of our efforts.

In both France and Germany the policy is to be sufficiently conservative so that whatever mistakes they make in their predictions, the cut will not exceed the rate of growth actually realized, and the growing stock will be maintained. With our decadent and overmature forests, such conservatism in the transition cycle is wasteful, for natural agencies are sure to reap the forest in human spares.

The conclusion is that we should not be satisfied with crude guesses as to the cutting cycle, and should seek means of actually predicting the growth and decadence of the timber, not only that which is left after cutting, but in the original forest as well.

Illustration—Munger—Western Yellow Pine in Oregon. First Cutting Cycle. First example of an attempt to formulate a plan of regulation of the cut suited to a transition cuttings is that discussed by Munger.* The conditions assumed

Species, Western Yellow Pine—Oregon.

Stock, 16,000 bd. ft. per acre.

Percentage to cut, 75%.

Stock remaining, 4,000 bd. ft. per acre.

Cutting cycle, 50 years

Rotation, 200 years.

Growth on cutover lands, 100 bd. ft. per year or 5,000 bd. ft. per acre in 50 years.

Proceedings of Society of American Foresters, Vol. X, No. 1, page 18; see also

The area included within the working circle will of course determine the annual cut. To discuss the problem this must be assumed. If 200,000 acres is taken, the cutting area annually is 4,000 acres, over which 75 per cent of the stand is reserved, leaving 4,000 bd. ft. per acre as a residual growing stock.

The cut for the first cycle of 50 years is based on the assumption of stage growth expressed by the formula, Annual cut $= \frac{X\% Ga}{cc}$ and on the area, will be,

$$\text{Annual cut} = \frac{.75 \times 16 \text{ M bd. ft.} \times 200,000 \text{ acres}}{50} \\ = 48,000 \text{ M bd. ft.}$$

This is a cut of 240 bd. ft. per acre annually.

The growth per acre annually, after cutting, is only 100 bd. ft. for 50 years. Leaving the residual growing stock of 4,000 bd. ft., the resultant stock per acre is reduced from 16,000 to 9,000 bd. ft. in this cycle by the removal of the overgrowth surplus.

The method of cutting proposed is horizontal, i.e., to given diameter or age, thus creating a felling reserve by the growth and maturing after the saws of the stand now containing 4,000 bd. ft. per acre on areas cut over. The fact that an equal growth may be taking place on these same stands before the saws, is offset against the decadence of the virgin stands—it is also true that the rate of increase on this growth of 4,000 bd. ft. after cutting is probably greater than in the virgin forest before cutting. The growth on this 4,000 bd. ft. in the virgin forest was not studied.

Second Cutting Cycle. Assumption of Normal Forest. This brings us to the end of the first cutting cycle. The one element which is based on research is the length of the cycle. The cut can be continued in the next cycle though at a reduced rate. Can it be continued indefinitely, and on what basis? To answer this question Munger assumes the existence of a normal (empirical) growing stock, based on the assumption that the residual growing stock of 4,000 bd. ft. per acre can be perpetually maintained, that the growth expressed by the increase on these stands, of 100 bd. ft. per year represents the total annual cut possible. In each subsequent cutting cycle, under the assumption the cut is,

$$\text{Annual cut} = 100 \text{ bd. ft.} \times 200,000 \text{ acres} \\ = 20,000,000 \text{ bd. ft.}$$

or 5/12ths of the cut permitted during the first cutting cycle.

Analysis of Data. Felling Reserve. This conception must be analyzed for if sound it could be used widely in American regulation. In the present instance, with 200 years, it is evident that the lower limitation of exploitable size or age was set at 100 or 1—cc years. In the first cycle, the average age and size of the merchantable timber was much above 150 and might even exceed 200 years. The felling reserve created at the first cutting cycle, however, will grow from 150 up to 200 years in maximum age and will average 175 or 1—½ cc years at end of the period, with an average stock of 6,500, or 4,000 + 2,500 bd. ft. per acre. The cut, each year, is 5,000 bd. ft. per acre on 4,000 acres (20,000 M bd. ft.), the ages ranging from 150 to 200 years on each acre.

Growth: The growth on these stands during the cutting cycle is,

$$\text{Present volume} + (\text{growth per year} \times \frac{1}{2} \text{ cc years}) \\ \text{or } 6,500 + 2,500 \text{ bd. ft.}$$

This 2,500 bd. ft. or 100 bd. ft. per acre for ½ cc (25 years) is the growth taking place ahead of the saws. The total growth is 5,000 bd. ft. and this amount is to be cut in the other half; or 2,500 bd. ft. was what took place behind the saws in the last cutting cycle and is added to the residual growing stock of 4,000 bd. ft. In this second cutting cycle 2,500 bd. ft. or ½ the total growth will again be put on behind the saws, and will turn form the felling reserve for the future.

But this "growth" must be further analyzed to understand the state of the forest and to comprehend how sustained yield is assumed.

Correlating age and diameter we can assume that the stand of 4,000 bd. ft. of residual

stock per acre is less than 150 years old, or below the diameter limit of cutting, it represents the growth of this 150 year period. No trees of this class can cut all the trees of the class above, 150 to 200 years, are to be cut when reached. But these latter trees are the same trees which in the previous cycle had 4,000 bd. ft. of volume. Since the cut takes the whole tree, the 5,000 bd. ft. of (100 bd. ft. per year) to be cut must include such part of this 4,000 bd. ft. as is in which mature plus the increase in size and volume of these same trees.

Growth of 100 bd. ft. is evidently not the mere current increase alone on the to be cut minus the volume possessed by these trees at the beginning of the . The *average stand* of 4,000 bd. ft. per acre is said to increase to 9,000 bd. ft. in s. Measured to the minimum exploitable diameter limit this 5,000 bd. ft. of " to be cut does not comprise the current growth of the trees *originally con-* 4,000 bd. ft., but instead the total volume in 50 years of all the trees which grow this residual growing stock, which was too small to cut, and into the exploitable plus the current growth of these trees after they enter the class.

Growth of Separate Age Classes. Supposing that of this residual 4,000 bd. ft., 1,000 bd. from 50 to 100 years old, and 3,000 bd. ft. from 100 to 150 years. During the next s, this 3,000 bd. ft. grows into the 150 to 200 year class, and becomes 5,000 bd. ft. s to be cut. It is evident that $\frac{3}{5}$ of the cut was laid on before the period and $\frac{2}{5}$ only constitutes growth for the 50-year period on the trees cut. It is evident that the $\frac{3}{5}$ growth is the total growth put on by the younger sizes e this 50 years, or by the rest of the forest or rest of the area, or remainder of age acre, and that 5,000 bd. ft. is the growth per acre for 50 years *not merely of now mature, but represents the growth of the forest as a whole.*

In practice, then, the difference or increase in merchantable volume of the entire er acre correctly represents the growth on all classes of trees and all ages in composed of a normal distribution of ages. (See § 62.)

In predicting this growth, the analysis of the forest into its respective age classes only show clearly on what classes the increase occurs, but will show up the ce, if one exists, between a normal and an irregular distribution, instead of assuming that the forest is already normal.

Growth Per Cent. Lacking this data on age classes, it is customary to predict growth s of a per cent of existing merchantable board foot volumes. This disregards ect of maturing age classes now unmerchantable. The per cent obtained is a n not merely of current growth but of volume on which it is laid, e.g., if the d. ft. in the above instance grew even at 2 per cent for 50 years, a cut of 130 per acre is indicated.

A trouble with our efforts to devise means of regulating our forests is that there ot exist in the minds of American foresters or owners a sufficient background wledge of the composition of a forest, the influence of the distribution of its sses, the difference in growth of these different age classes, or the relation of cessive maturing of age classes in determining the annual sustained yield. In ample (§ 137), the elements not determined were, first, the distribution of age ; second, the per cent of total area occupied by the 12,000 bd. ft. of stand d, and by the 4,000 bd. ft. left plus the unmerchantable age classes and repro- ; third, the true growth per acre of these younger age classes, or the effect of ng timber on the possible cut.

As a result, while the outward form of the conclusions reached is sound, and a ed yield of 100 bd. ft. per acre annually is indicated after 50 years, yet the actual ions as soon as we begin to analyze these assumptions may not bear out these sions.

Actual Versus Assumed Age Classes. If the stand is actually from 0 to 200 years old, the form of a normal forest, four age classes of 50 years each must stand on re. Each year 4,000 out of 200,000 acres is cut, removing 20,000,000 bd. ft. But same 4,000 acres, three other age classes are present, occupying $\frac{3}{4}$ of the area. al cut is taken from $\frac{1}{4}$ of each acre, or from 1,000 acres, and the stand on one

full acre of this age class if segregated is 20,000 bd. ft., while on the second stand would be 12,000 bd. ft. ($4 \times 3,000$)—on the third acre 4,000 bd. ft. ($4 \times 1,000$) while the fourth acre is covered by young growth. Consequently, the per cent cut, if a constant reserve of 4,000 bd. ft. per acre is maintained, will be but 55 per cent as against 75 per cent, in the first cut. Unless these premises hold the assumption of 4,000 bd. ft. per acre as a residual growing stock is incorrect.

But the most sweeping assumption is that after the removal of the excessive in the first cutting cycle, the arrangement of age classes remaining is normal, as indicated. The chances are that the overmature timber removed in the first cut occupies more than 25 per cent of the area—probably also, the average age of the remaining timber may be greater than 100 or 200 years when cut,—and 2 cycles required to reduce the surplus, or else the cycle chosen is too short. The plan, *which assumes normality following the first cut, makes no provision for securing normality in the second cycle, as indicated, the actual distribution of ages is decidedly abnormal.*

Difference in Basis of Cut Between First and Second Cycles. In the French method of 1883 (§87-88) after the cutting cycle and per cent of total volume to be cut had been theoretically computed, as $\frac{1}{3}$ r and $\frac{5}{8}$ Ga respectively, no such assumption of normality is made. Were the original formula and method to be applied to the cut in the second cycle, as it was to the transition cutting, we would have the following comparison per acre.

By method of 1883

$$\text{Annual cut} = \frac{.62\frac{1}{2} \times 6500 \text{ bd. ft. per acre}}{66 \text{ years}} = 61 \text{ bd. ft. per acre per year}$$

$$\text{By Von Mantel's} = \frac{6500 \text{ bd. ft.}}{100 \text{ years}} = 65 \text{ bd. ft. per acre per year}$$

By Munger's, basis of $\frac{1}{4}$ r and $\frac{5}{9}$ Ga.

$$\text{Annual cut} = \frac{.55\frac{1}{2} \times 6500}{50} = 73 \text{ bd. ft. per acre per year}$$

But in the second cycle, with surplus removed, *this method is already obsolete.* The French assume an allotment of the upper $\frac{1}{3}$ of the stand for the period, and since the cutting cycle is not $\frac{1}{3}$ r but a period of but 5 to 8 years only, *the felling series is not coincident with the cutting cycle at all, but is insignificant, and the actual average age of timber in the upper third of the stand should be $\frac{5}{8}$ of the total and not $\frac{1}{3}$ of this, or 5,000 and not 2,500 bd. ft. above the 4,000 bd. ft. reserve, thus providing an average cutting age of 100 or 200 years, with timber probably varying from 100 to 196 to $r + \frac{1}{2}$ cc or 204 years in age.* Substituting 9,000 for 6,500 bd. ft. the result would be:

$$\text{By method of 1883, annual cut} = \frac{.62\frac{1}{2} \times 9000}{66} = 85 \text{ feet per year per acre.}$$

Recognition of Growth in Second Cycle. Because of our long cutting cycle, this French allotment method will not work.* What Munger actually assumes is, although but 6,500 bd. ft. is on hand per acre, there will be 9,000 bd. ft. on the cut area when it is to be cut, hence the annual cut =

$$\frac{.55\frac{1}{2} \times 9000}{50} = 100 \text{ bd. ft. per year}$$

The specific difference in management caused by the shorter cutting cycle of 10 years is further illustrated.

With a cycle of 10 years instead of 50 years, the area cut over annually would be

* We must bear in mind that the French method of 1883 is applied to selection of silver fir and spruce. They would never use the method for pine stands with growth of even-aged trees, nor would they calculate ahead for more than 20 to 30 years. They are apt to discard refinements as immaterial to the result.

We must also bear in mind that the reason that they would not do so is the unsuitability of a short cutting cycle, rather than the difference in the silvicultural systems. H.

instead of 4,000 acres, or $1/10$ of the total area of 200,000 acres. The total finger's figures is 100 bd. ft. $\times$ 200,000 acres or 20,000,000 bd. ft. Concentrated acres, the annual cut per acre on the cutting area only is but 1,000 instead of 10,000 bd. ft. which means that only the trees which have fully matured need to be cut, there is no felling reserve worth mentioning. The acre is cut 5 times in 50 years, yielding 1,000 bd. ft. at each cutting. But with a cutting cycle of 50 years, this reserve and the growth which takes place during the cycle are the factors which limit of a cut of 5,000 instead of 1,000 bd. ft. per acre and since it is evident that 2,500 bd. ft. per acre is present on the area as a whole (2,500 bd. ft. of which 1,000 is the reserve), the assumption of a cut equal to 55 per cent of this stand for the cycle is reasonable. To get 100 bd. ft. per acre, 77 per cent must be cut, or $\frac{5000}{6500}$ of the stand and 77 per cent can be cut, since it is cut annually on an area which has put on growth and contains actually 9,000 bd. ft. per acre, not 6,500 bd. ft.

For these reasons, the formula, $\text{annual cut} = \frac{x\% \text{ Ga}}{cc}$ cannot be used in the second cycle, for growth must here be recognized as a material factor in the cut.

Determining Condition of Normality. The relation of volumes, as $3/8$ to $5/8$ by the French method of 1883, is not the relation actually existing in the forest, but that assumed to exist after one cutting cycle, but it is the theoretically normal relation which should exist in a forest which has a normal form, and is the density or degree of stocking of each age class,—a normal arrangement on a basis of empirical stocking. The real work of regulation is to secure this in the actual stand, and this will be our problem in the second cycle and on. But we must first ascertain as did the French, what is the normal proportion of volumes to be striven for, and what actual proportions exist in the forest. The basis for the separation of age classes in the forest, on the basis of age, area and volume produced or yield per acre, regardless of whether this forest is even-aged in form. This same information is needed, not merely for a basis of regulation after the surplus is cut, but for the initial determination of the cycle, and of the annual cut.

Summary of Principles. To sum up: *a.* Unless the species constituting the main volume of the stand are merchantable, regulation of the cut in the first cycle is preliminary in form and confined to the valuable merchantable percentage, which should be treated if possible for a sustained yield based on growth,—but this cannot always be done.

When the main yield becomes merchantable and accessible, the first cutting cycle is transitional, involving the creation of a felling reserve, and of a long, even up to $1/2$ or 1 years.

Although the length of the period must be based on studies of growth on other lands, the amount of the cut in the first cutting cycle may for the present and in absence of proper growth data be fixed on the basis that it will balance growth in the virgin stands previous to cutting. The annual cut of timber now mature then becomes

$$\frac{x\% \text{ Ga}}{cc}$$

The current growth per year on the stand left per acre after cutting, if added to include the total volume of trees maturing or becoming merchantable, is sometimes assumed to indicate the sustained annual cut.

This assumes a normal forest, which does not exist in fact.

We need to know the composition and yield per acre of the forest by

separate age classes, in order, first, to determine what is a normal second, what is a sustained yield, third, what steps should be taken to attain these objects.

After determining the length of the initial cutting cycle, and the volume of the stand to cut, the general method of regulation, applicable to American forests is,

1. The annual cut, during the first or transitional felling cycles should be:
 - a. X per cent of the present merchantable volume, which will constitute the exploitable age or size classes, which should be between $r - \frac{1}{2}cc$ years.
 - b. Plus the net growth in volume on these stands before cutting (total growth minus decadence), which is $\frac{1}{2}$ the growth in volume on the stands between $r - \frac{1}{2}cc$ and $r - cc$ years.
 - c. Plus $\frac{1}{2}$ the total growth for cc years of the remaining stands in the forest including all age classes, which is equivalent to $\frac{1}{2}$ the volume and $\frac{1}{2}$ the growth for cc years on $\frac{1}{2}$ of the stand that would mature during this period cc , and is equal to all stands between $r - \frac{1}{2}cc$ and $r - cc$ years.
2. The cut during the second cutting cycle should be,
 - a. The felling reserve, which is the other half of the volume of the growth of the stands maturing during cutting cycle,
 - b. Plus an additional quantity made up from the growth of the stands during this period cc and represented by growth during this period on the felling reserve plus the maturing of stands into the exploitable class and growth thereon before cutting. In a normal forest this would give a total approximately equal to the volume of the felling reserve. Together, these elements equal the volume at beginning of cycle, of stands between r and $r - cc$ years, plus $\frac{1}{2}$ the growth during the cycle.
3. The maintenance of the cut in subsequent cycles therefore depends on whether the forest, after the first cutting cycle, is normal in distribution of age classes.
4. Regulation of the annual cut as between cutting cycles is impossible without a knowledge of the composition of the forest with respect to area, age and volume of each age class, and a yield table based on empirical average yields for the forest unit. It is best accomplished by
 - a. Ability to modify or reduce the per cent of the cut in the first cutting cycle and thus shorten the cycle and hold over the volume to the second cycle.
 - b. Ability to reduce the total annual cut from the forest in the first or a long first cutting cycle so as to permit the accumulation of a sustained cut per acre in the succeeding cycle.
 - c. Ability to predict the cut of immature timber and the proper area and per cent of the rotation which it will occupy.

139. Separation of the Forest into Age Classes. The basis of separation of the stands comprising a working group is fundamentally age;—since the time required by growth will eventually govern the rate of cutting. In a forest naturally composed of even-aged stands, which can be mapped and the average age is easily determined, age will be directly ascertained by

ple trees, and the age classes can be separated by area and by volume forest during the forest survey.

eparation of age classes in the many-aged form of forest cannot be y area mapping, but must be correlated with average diameter—a e sanctioned by the French in 1883 as the basis of their method of ng many-aged forests.*

for *Empirical Yield Table*. Where age and yield per acre can be used, s of regulation becomes *the yield table giving volume per acre at different* But in the construction of this table, which is by selection of plots, it er possible nor necessary to attempt to secure average stands or yields, will represent the empirical or actual condition of the forest. Yet er data is what is required rather than selected yields which represent r average of stocking, approaching "normality."

mination of a *Reduction Per Cent*. The principle which must be applied e this problem is to determine the relation of the volumes of the t age classes in the forest to the corresponding volumes for the ges in the yield table, on the basis of equal areas. On this basis a n per cent is obtained and the yield of the age classes in the forest n be gauged by the yield table after reducing this table to the empirical d by applying this reduction per cent. If for instance an age class but 50 per cent of normal density its future yield will be computed er cent of the yield shown in the normal table. This basis is extremely ative, since it is well known that sparsely stocked stands tend to p with increasing age.

e are several variations in the methods of applying this principle, but e form it must be worked out for every forest on which regulation of b contemplated. The volume per acre of a given age class is a function ily of age, and secondly of density of stocking. The three factors must be determined, then, are age, area and volume. In the yield he normal relation of these three factors is shown, areas being stand- l as one acre.

Summary of Possible Conditions. (1) *For Even-aged Mapped Areas*. fferent conditions encountered may be summed up as follows:

lem 1. Even-aged mapped areas. Age, volume and area of each age n the forest is directly ascertained. Usually true of regulated forests ed by clear cutting or shelterwood system, and can be found for sprout s, or forest originating on burns.

tion. Divide the yield per acre of the age class by the yield from This gives the reduction per cent, separately for each age class, by its future yield can be predicted by applying this per cent to the yields table for future years.

stands of less than merchantable age, this per cent of normality must ectly estimated by inspection, based on silvicultural knowledge of the

* For lodgepole pine, this normality per cent is reduced by overstock- greater degree than by understocking.

er to § 87-88.

ilization and Management of Lodgepole Pine in the Rocky Mountains by D. T. Bul. 234 U. S. Dept. Agr., Page 36, Table 18.

(2) *For Even-aged Stands whose Volumes but not Areas are Problem 2.* Age and volume of each age class can be found. The area occupied is not separately mapped, but the total area occupied is found for all age classes.

Solution. This problem is easily soluble if it can be assumed an average reduction per cent, applying equally to all age classes, with the purposes of regulation, as follows:

1. Divide the volume of each age class by the yield of one acre of given age, from the yield table. This gives the *area* which would be occupied by the age class if the stand were fully or 100 per cent stocked.

2. Obtain the total of fully or 100 per cent stocked areas by adding together the areas of all merchantable age classes.

3. By comparing this area with the total area actually occupied, the sum of the age classes the density or reduction per cent would be obtained. But this process disregards actual silvicultural conditions and young trees. It is far preferable to

4. Subtract from the total area the area stocked with young saplings, poles and seedlings established,—the residue is the area stocked with merchantable timber. Divide the “fully stocked” net area obtained above, by this net area stocked with merchantable timber. This gives the density of stocking of the age classes whose volume can be measured. The per cent is assumed to apply equally to all these merchantable age classes.

5. If the area “fully or 100 per cent stocked” thus obtained for each age class is taken as the basis, and is divided by the density per cent obtained, the area in acres theoretically occupied by each age class of merchantable timber may be found. This method of solution fulfills all practical conditions of regulation.

141. Illustration from Tusayan National Forest. The volume of this stand has been previously separated into veterans, mature, and blackjack, but the areas have been separated directly in the field.

Net area in timber, original growth,	52,004 acres.
Deducted for saplings and seedlings,	13,002 acres—25 per cent
Deducted for poles,	6,500 acres—12½ per cent
Net area occupied by merchantable timber,	32,502 acres.
Determination of the reduction per cent, or factor of density.	

Age class	Age years	Yield per acre from yield table ft. B.M.	Area fully or 100 per cent stocked* acres	Per cent of area in each age class
Veteran	300	18,200	8,345	58.3
Mature	200	25,300	1,745	12.2
Blackjack	100	11,300	4,211	29.5

Total fully stocked

14,301

Reduction or density per cent

$$\frac{14301}{32502} = 44 \text{ per cent}$$

Area in each age class.

$$\text{Ratio } \frac{100}{44} = 2.2727$$

* obtained by dividing the volume in each age class in the forest by the yield shown in column 2.

Veterans	$8,345 \times 2.2727 =$	18,966 acres
Mature	$1,745 \times 2.2727 =$	3,966 acres
Blackjack	$4,211 \times 2.2727 =$	9,570 acres
Poles		6,500 acres
Saplings and seedlings		13,002 acres

Total area 52,004 acres

dict the yield of these age classes, whose *area* and *age* we now have, the yield must be reduced in this instance to 44 per cent of its original value. This stand stands now showing a density of 44 per cent of normal will continue to be in this relation or better, and that if better the surplus is not considered. The yield table so obtained is a true empirical or actual average yield, adapted to conditions of the forest or unit as a whole or to the type or working unit or group in which it was constructed.

(3) **For Many-aged Stands.** *Problem 3.* Volume and diameter are readily determined, but age classes cannot be directly determined. This is the typical problem for many-aged forests or forests in which the age classes are not amenable to separation by area. The average age of different age classes is not amenable to determination directly. Yet since age and the separation of age classes are fundamental to regulation, some means of separation and determination must be found to permit of any systematic regulation whatever.

Relation of Diameter and Age. Solution. Diameters of the trees in the stand are readily determined. Diameter is a rough indication of the age of the trees. By determining the average relation between diameter and age, whether this be for total age or merely for current growth for a lesser period, the time factor (age) is supplied and the growth rate of the stand may be ascertained.

The simplest principle of separation is that by diameter classes or groups. The rate of diameter growth is measured on a large number of trees to eliminate individual variations. The curve of growth, to be accurate, *should be based on diameter and not on age*. The resultant table should show the average age of trees of each diameter class.

As to the period of suppression common to trees of tolerant species growing in many-aged forests, the absolute age of such trees is valueless for purposes of regulation, since the individual trees, if they had the benefit of freedom from suppression, would mature without this period of delayed development. For this reason, one of two modifications are usually made in this curve—either the juvenile period of growth is omitted, and the curve indicates the number of years it requires for trees of given sizes to reach the next larger size,—or else if the total age is shown, this juvenile period is taken from trees which have not been suppressed.

Relation of the Yield Table. The yields per acre at different ages are now determined primarily upon the sizes of the trees, their average volumes, and the number of trees of the given size which would stand on one acre of ground. The same relation as before exists between the normal or well stocked forest and the average or empirical forest. The yields for a normal or full stocking forest at different ages must be found, in the form of a yield table, in order to determine the normal relation or proportion existing between volumes on one acre at different ages, so that this relation or percentage of increase

from decade to decade, which is the law of growth of the stand, may be applied to determine the actual density of the forest in question, and to predict the yields of existing stands.

For instance, in the French method of 1883 the relation of $\frac{5}{8}$ to $\frac{3}{4}$ it was stated should exist between stands respectively over $\frac{2}{3}$ r in a stand between $\frac{2}{3}$ and $\frac{1}{3}$ r, was first found for an assumed "normal" series of classes, in which the volume of the stand was calculated for the normal and the average growth relation between the two groups roughly determined (§ 87). The establishment of this same relation is sought in the forest—its existence is the proof of empirical normality, independent of density.

Derivation of the Normal Yield Table. From Crown Spread. This "normal" yield table, from which the percentage or proportional relation of stands of different ages or average sizes can be found may be worked out under different conditions on a sound basis in one of two ways. First, the average growth space demanded by trees of different diameters may be found. Crown spread is almost always directly related to diameter, and is a direct indication of the space required by a tree. If the proportional space per tree for trees of different diameters, can be found, thus giving a curve of the relations between *number of trees per acre* for different diameters, it makes no difference whether on the whole this curve gives too many trees per acre, the proportion is correct as between classes, for it is as easy to reduce the number giving 110 per cent of the "normal" number, to 60 per cent as it is to increase one giving 90 per cent, to 60 per cent. The volume of trees of these proportions gives the normal yields per acre, while the age is taken from the diameter.

143. Illustration—from "Yellow Poplar in Tennessee" by W. W. Ashe, Bulletin of the State Geological Survey:

TABLE 14. Number of trees in different diameter classes per acre, required to produce a continuous yield from a fully stocked growth selection stand of pure poplar.

Diameter classes. Inches	Number of trees per acre on average quality site	Approximate per cent of each diameter class which should exist in a normal stand
2-4	280	54
5-8	151	30
9-12	57	11
13-16	19	4
17-20	5	1
above 20	1	.30
	513	

Ashe then states, "Since this table is based on fully stocked pure stands, it is necessary in the consideration of a mixed stand to ascertain the average number of trees in the different diameter classes per acre. The relation of this number in each diameter class to the corresponding table number gives the proportional annual yield which may be expected from this diameter class when mature, that is when larger than the diameter in inches." If in place of 19 trees to the acre in the 13 to 16 inch diameter class there were 6 trees, the proportion of stocking would be $\frac{6}{19}$ as far as this diameter class was concerned. The annual yield per acre from a fully stocked stand is 430 board feet.

ntly the annual yield with the proportion of stocking given would be $10 = 135$ ft.

Illustration, application of the principle of proportion or reduction per cent to a so-called normal stand and yield table and the actual forest is based on determined directly by crown spread.

al difficulty in this method lies in forests containing decadent stands of over-maturation, for here, not only does the space required by an old tree exceed the space indicated by its crown as compared to a young tree, but the stand is losing its vitality and is becoming open by the death of individuals.

Plots. For these reasons, the second method proposed below is applicable for such forests. This consists of actually laying out plots, in each composed of trees of as nearly as possible the same size class, and determining on an area basis, which takes into account all the silvicultural factors affecting the stand, the number of trees on the acre and their average diameter volume, and from this size, the age of the stand as in the first method. If the table giving number of trees per acre for a normal stand is found for different ages, the results can be used to predict the yields even of mixed stands of hardwoods.

In any form or other, this principle must always be used, and will serve as a means of applying to the exact conditions of stocking in the forest the principle of growth as ascertained by a special study of selected stands and conditions. In the illustration given, the proportion between the number of trees of different diameters is the basis of comparison. In even-aged stands, the proportion between volumes is used. But the final result in each case is an empirical yield table adapted to the degree of stocking of the forest unit to be regulated.

A System of Regulation of Yield, for Many-aged or Selection Forests.

on Diameters and Diameter Growth. Preliminary in character, and discussed with the yield table. Data Needed. The following data is needed:

1. A table showing the number of trees and volume of each diameter class on the average acre in the forest.

2. A table of growth of trees of different diameters, preferably showing number of years required to grow one inch.

3. A volume table, based on diameter, applicable to the site class or average conditions for the unit.

The principle to be applied is explained in paragraph 127. A cutting cycle is determined on, which bears a reasonable relation to the rotation, and conforms with the required conditions of logging and silviculture. The minimum exploitable size or diameter is fixed, which conforms to those conditions.

The cut for the first cycle will include all trees above this size with $\frac{1}{2}$ the growth during the cycle plus a volume equal to all trees in a diameter class below this size, whose scope coincides with a period equal to $\frac{1}{2}$ the length of the cycle, to which $\frac{1}{2}$ the growth on these trees for the cycle is added.

Illustration—with scattered shortleaf and loblolly pine growing with mixed hardwoods. (Southern States.)

Logging Cycle. On basis of logging conditions, condition of forest with respect to rotation of age classes, and silvicultural needs, the per cent of the stand to remove in the cutting cycle was set at 83 per cent and the minimum exploitable diameter limit for this called for in the cut, was 15 inches.

On basis of rate of growth of the trees in diameter, stand per acre desired cut, and number of years required to produce this yield from the existing forest, length of the cutting cycle was fixed at 20 years.

Calculation of the Possible Cut.—*Calculation of Cut in First 20-Year Cycle.* growth in diameter for $\frac{1}{2}$ the period, or 10 years, 2.5 inches. Hence, trees mature cut within period of 20 years, are those from 12.5 to 15 inches in diameter.

Volume of trees above 15 inches	1,408 M. bd.
Growth in 20 years (total growth less 15 per cent for losses)	403 M. bd. ft.
$\frac{1}{2}$ total growth is cut	201 M. bd.
Volume of trees from 12.5 to 15 inches	147 M. bd.
Growth in 20 years on these trees	248 M. bd. ft.
$\frac{1}{2}$ growth is cut	124 M. bd.
Total to cut within 20 years	1,880 M. bd.
Or, total volume of all trees above 12.5 inches	1,555 M. bd.
$\frac{1}{2}$ growth in 20 years	325 M. bd.

Total cut

Calculation of Cut in Second Period of 20 Years. During this period, the age class 12.5 inches downward is to be cut. The diameter group includes 20 years. If the rate of 5 inches in 20 years holds good, this group embraces trees now 7.5 inches in diameter.

Twenty years growth during the first period brings this group above 12.5 inches. The volume thus maturing is that of the original group, plus 20 years growth less the losses occurring during the period.

With the same minimum exploitable diameter as before, namely, 15 inches, this group will be cut during the next 20-year cycle, plus $\frac{1}{2}$ the growth for this period.

Volume, at end of period, of trees then above 12.5 inches, being the present volume of trees 7.5 to 12.5 inches, plus net growth for 20 years	790 M. bd.
Growth for next 20 years	400 M. bd. ft.
$\frac{1}{2}$ growth, cut in next period	200 M. bd.

Total cut for second period

This general method is not based on cutting a definite number of trees (as in the case of a forest), but upon the volume produced by the existing forest, computed at by knowing the number and size of the trees in the forest.

146. Factor of Loss of Numbers. The weak point in the method of prediction of growth, based on number of trees which will survive, is that the actual net growth in any forest is the difference in volume of the successive age classes, found by comparing the merchantable volume of the living trees at one period with those of a succeeding period. A "normal" acre of forest would help to indicate the progressive reduction in numbers with time. The improvement which this method evidently needs is the application of a yield table or guide in determining, at least, the loss in numbers, instead of having to guess at this vital factor. (See Ashe's illustration, § 143.) A great difference between forests under intensive management and those under forest being brought under regulation is that in the former, the trees which normally die will be cut instead as thinnings or salvaged and are included in the yield, while in the latter, their volume at the beginning of the period is a net reduction from the total increase and is lost.

en it is necessary to predict this growth by measurement of growth per applied to the total number of trees, as in the above example, the loss es must be offset against this growth in volume. In the example given, ck of data, this loss was arrived at rather arbitrarily by deducting 15 ent of the final volume as lost during the 20 year period, this amount 44 per cent of the assumed or indicated total growth had all the trees ved. The diminution in number of trees, by diameter classes, as indi- in a stand table or a normal acre, would show the average loss in a al many-aged forest in which no cutting whatever was done, and all eventually disappeared. In forests cut over at intervals, this rate of of trees is reduced materially. Graves, in the "Adirondack Spruce" ed that on cutover land it could be ignored altogether. As it stands, rue growth realized depends,

upon the effect of cutting on the rate of survival of trees left after ng, as well as upon their increased growth.

upon the ability of the forester to secure or salvage the trees which d otherwise be lost. This is largely a function of the conditions which it of a short cutting cycle, the probability of salvage increasing as the shortens.

the true rate and amount of growth, when predicted from growth of trees, fall somewhere between that indicated by survival of all trees, and that ated by the diminishing curve of numbers of trees per acre based on eter. Only a careful study of the composition of the forest with respect owth will give accurate knowledge of this factor. In India it is approx- ed by guess based on the judgment and silvicultural knowledge of the ster.

his data, taken from an actual stand on Henry Hardtner's forest at Urania, isiana, brings out some of the difficulties in actually bridging the gap een theory and practice in securing sustained yield on a forest not now er regulation. This stand had been logged once, removing large mature s. The cutting cycle suggested is therefore in effect a second cycle—the cut was to about 17 or 18 inches. In spite of the conservative (high) nch limit, leaving 17 per cent of timber now merchantable, the second ear cycle gives a prospective sustained yield of approximately 50 per of that in the first cycle.

7. **Determining of Normality.** To regulate or equalize the cut for these cycles, which is evidently abnormal, a comparison could be made between stands required for a normal forest and those in the actual forest. Data this is lacking in the illustration. Granting that the 20 year cycle is the per subdivision or period of the rotation, which for this forest is 80 years, have four age groups of 20 years each. The average age of the mer- antable timber in the second cutting cycle might be set at $1 - \frac{1}{2}$ cc or 70 rs, and the cutting age 1 or 80 years (§ 127).

he approximate diameters are respectively:

for 0-20 years	0-4"
for 21-40 years	5-9"
for 41-60 years	10-15"
over 60 years	16" and over.

The normality of the stand, if based on the 20 year cutting cycle to the maximum cut per cent per acre, would be determined by the volume available for cutting in the successive periods, and not as in the French system of 1883 upon the present volume.

Now, in order to confine the cutting during the first cycle to trees now 60 years of age, or falling in the last period, the minimum exploitable must be set at 70 years, and the diameter corresponding to this mark the minimum limit of cutting. This, by the relations explained in § 127, will result in cutting a volume equivalent to that of the 60 to 80 year 2nd cycle only, and will conform to a rotation of 80 years, reduce the cut in the first cycle by raising the diameter, and tend to equalize the cut from the first and second cycles. This method consists merely in adopting a short cutting cycle and a long rotation simultaneously.

But the same general result can be obtained with a *long* cutting cycle, provided the cut is actually prolonged to last throughout the cycle, and does not proceed to remove all the available timber within a shorter period. This means reducing the amount of the annual cut, and acreage cut over annual rotation to the proper proportion of the total available for the cycle. The same principles will apply in determining the annual cut as were illustrated in the above example.

148. Overcutting. *The securing of a sustained yield and the mere prolonging of the cut are two different things.* The latter is accomplished (as in the above illustration) if the second cut can begin in the year when the first cut terminates. But the cut in the second period is but 50 per cent of that in the first period (and in Munger's illustration, 42 per cent). The reduction in production is partly due to the removal of an actual surplus stock accumulated by overmaturity. But it may also indicate actual overcutting.** In such an instance, in each of two or three successive cycles, the diameter limit must be lowered, thus holding up the apparent yield but at the expense of the forest capital which is being depleted. The level of sustained production must obviously be determined—a short cutting cycle based on supplementing the cut from forest capital is obviously an absurdity—for the “surplus” created by successively heavier per cents of cutting per acre in effect indicates successively longer periods before the recovery of the forest or a second cut on the same area, and demands successively larger present quantities of growth stock or surplus if the cut is to continue throughout this cutting cycle. In mixed forests the successive cutting of different species as they become marketable has frequently prolonged the ordinary logging operations over two or three cutting cycles, without in any way providing for a sustained yield in the end. The usual result of such overcutting is a final clean cut and abandonment of the enterprise.

* Judging from data submitted to a bond house by a well known paper company concerns, through vitally concerned with a sustained yield, are merely prolonging the cut. T. S. W., Jr.

** It is virtually paying unearned dividends (a) *out of surplus* so long as there is growing stock but (b) *out of capital* when this surplus stock is disposed of; (a) is sound business while (b) is usually contrary to sound business principles. T. S. W., Jr.

the above illustration, a reduction to 50 per cent of the first cut, on a cutting limit, may permit of continuing the cut every 20 years, on reduced basis. Or the forest may be capable of a sustained output during this figure. This would be the case if the 40 to 60 year age class, 15 inches in diameter on which the cut and prediction of yield is based, is deficient in numbers. Here again is where the normal acre, showing distribution of numbers, would serve as an indication.

Method of Regulating Yield. To regulate or better distribute such a stand, the volume of the cut per year in the first period must be reduced, carrying over some of the surplus to the second period. This can be done by raising the diameter limit of cutting during this period, by one or two inches, thus shifting a portion of the cut to the second period. Beyond the first two periods, the distribution of age classes and regulation of the cut by this method is not feasible; nor would it be advisable. The graphical representation of trees required is subject to great reduction by fire, disease and other natural losses. Inspection is about as reliable as counting to determine the success of reproduction and degree of stocking by seed and saplings, and since the trees have no merchantable volume they are not tallied.

Summary. For the regulation of many-aged selection forests, where it is not possible to determine age of stands from age of individual trees, age of stands must be determined from diameter of trees, by depending on the general laws of relation between diameter and age for trees.

The cutting limit can correspond to a given diameter, and the volume of timber available for cutting in the first cycle to the volume above this diameter, plus the volume of all trees which would reach this diameter in $\frac{1}{2}$ the cutting cycle, plus $\frac{1}{2}$ the growth on this total volume (§ 127).

The cut in the second cycle will be equal to the volume of timber which at that time has reached the same diameter limit as indicated above, namely, diameter representing an age $\frac{1}{2}$ cycle years less than that of the cutting limit.

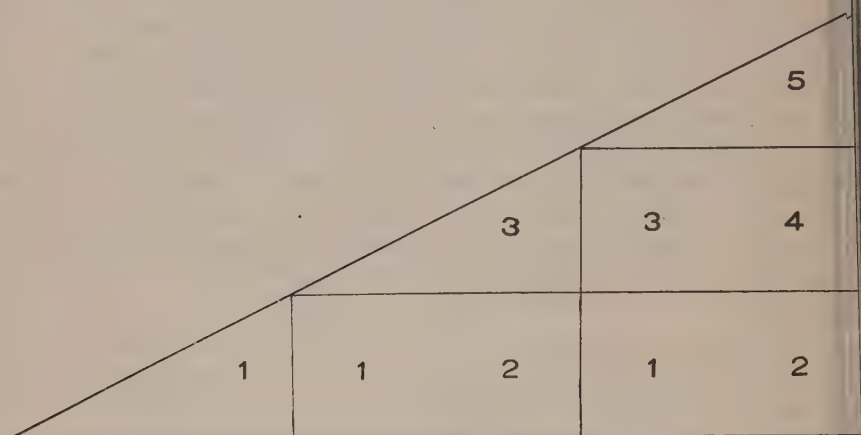
Comparison with French System of 1883. The annual cut can be obtained if necessary at a regular volume by raising or lowering the diameter limit of cutting, based on comparison of yields thus secured in the two cutting cycles.

In comparison of this general method with that of the French system of 1883 it shows that this latter method pays no attention to the quantity or enumeration of growing stock of the first third of the rotation leaving this to silvicultural practice, being assured it is probably sufficient (with the silver fir and spruce stands to which it is usually applied. T. S. W., Jr.). The actual stand is completed for the entire merchantable stand. This is comparatively simple for us to secure, by assembling a stand table for the portion tallied, and expressing it as applying to the average acre. It is not necessary to count every tree, either for estimating volume, or securing distribution of

The student of course must recognize the silvical disadvantage of strictly adhering to a rigid diameter limit; in practice mature trees below the limit are cut and young above the limit retained.

diameters. The percentage relation taken from a stand table prepared for a portion of the area will give this for the whole.

The French, by a crude and inaccurate assumption (see discussion in chapter 10) arrive at the conclusion that if the second third of the area or age class should produce three units of volume, the same stand in the third period should have produced three units. This is based on the Von Mantel's principle that mean and current growth should coincide throughout the rotation, hence the growing stock has the same value shown below



and the removal of the entire volume on the last third of the area and rotation is possible in $\frac{1}{3}$ r years. In practice, the volume of the upper third of the stock grows to the age of the rotation before it is cut, due to the cutting cycle.

Protests have been voiced against some of the methods here discussed. American regulation because said methods are not based on accurate mathematical data and principles but "pass from one assumption to another on the basis of accuracy is completely destroyed." If anything is more apparently inaccurate, and based on ranker assumption than this French method of 1883 it has not yet been found, yet it has worked successfully for three or eight years, and furnished a workable solution for the problem of regulation of many-aged forests.*

Improvements Possible for American Application. Instead of basing the rotation or age classes upon the assumption that diameter growth is practically uniform, and that trees of $\frac{1}{3}$ the final average size required in the rotation are also $\frac{1}{3}$ the age,—the same proportion holding for $\frac{2}{3}$ —the actual relations may be worked out from local growth studies. When the fundamental relations between size and age are established, the relations which shall

* It has been successful because there is frequent stock taking, because it has been applied by experienced foresters, and because there is good silvicultural practice in the forest with due regard to a proper distribution of size classes (without unnecessary refinements). T. S. W., Jr.

between the volumes of the different age groups or classes can be deduced by these studies and the construction of normal acres. This period in the French system is independent of the cutting cycle and felling cycle. Here as repeatedly pointed out, the latter factors are too great to be ignored and the form and volume of the growing stock required must be computed with respect to the felling series. We cannot import a method as simple and crude as this, without adapting it to our forest and economic conditions. The desire of American foresters for mathematical accuracy born in a large part from the lack of opportunity for the practical solution of growth problems, can still be gratified to a considerable extent without splitting too many hairs.

The progress of the forest towards normality of stocking, obtained by the method through conservative cutting, and by their curves showing the relation of the number of trees per acre in actual versus normal forest, will be seriously delayed here by the removal of excess overmature stock, but can be secured by raising the diameter limit of cutting, where shorter cycles are possible, or by extending the length of the cutting cycle when the cut per acre cannot be reduced because of danger of blowdown or other silvicultural considerations.

Determining the Allowed Cut. Sustained yield in many-aged forests means, first, the determination of the "allowed cut" or actual production per year, and the adjustment of the cut to leave the forest in shape to produce this. The reason for success with the method of 1883 is that the indicated annual cut on the basis proposed, is practically certain to be somewhat, but not much, less than the growth; second, it effects a removal of surplus large trees, or its conservation as needed, and third, it increases only as the forest becomes more densely stocked through better silviculture. Until our overmature and decadent stock is removed, conservative cutting should be based on cutting the smallest possible per cent of the standing timber per acre, and the largest possible cut per year which will enable us to cover the forest during the cutting cycle, which by the above considerations would be as short as possible. At best we will be forced to adopt long cycles on National Forests, where regulation is feasible. The stock needs reduction, and the first problem is to secure better distribution of age classes or prevent the further disturbance, by overcutting, of such distribution as may already exist.

Summary of Distinctive Characteristics of American Regulation. The distinctive features of the method proposed, as applicable to all forms of forests in America, are:

A period for regulation of yield, which is based upon and coincides with a cutting cycle. This may give place later to periods *exceeding* a cutting cycle in length (provided the cutting cycles can be shortened so as to become a negligible factor), but never to be shorter than the required cutting cycle.

The length of the cutting cycle to be the governing factor in determining the regulation of the cut and to be based upon the existing conditions, scientific, and economic.

Regulation of the annual cut to be effected by lengthening or shortening

the initial or transition cutting cycle, corresponding to increase or decrease in the per cent of the stand per acre taken in the first cut.

4. The amount of the annual cut to depend upon the cutting cycle, per volume, per cent to cut, growth of old stands and inclusion of the mature crops of young timber entering the exploitable class within the cycle.

5. The result of the first cutting cycle to be the establishment of a felling reserve and cutting series of normal arrangement for continuance of timber in the second cycle.

6. Regulation of yield to be based on the use of a yield table and reduction per cent, the separation of age classes in the forest, and the prediction of empirical or actual growth, including decadence, on the age classes as they exist in the forest.

The last requirement is so obviously in keeping with universal principles in forestry that only the assumed difficulties and expense of obtaining the required data has held back the science of regulation on our National Forests and at present, the tendency is to go ahead at once with whatever data is available, to formulate some basis of regulation wherever it is needed.

152. Quiz. Why are cutting cycles for mixed stands preliminary?

Why is a study of growth essential?

When does growth balance decadence?

Explain formula cited in § 134.

Can the growth of mature timber be neglected in a long cutting cycle?

Can the length of cutting cycle be guessed at?

Discuss Munger formula; felling reserve.

Why must age classes be analyzed?

What is the danger of using growth per cent?

Why must condition of normality be determined?

Explain how empirical yield tables are necessary in regulation.

How is a "reduction per cent" obtained for even-aged areas where mapped where areas are not separated?

In all-aged stands how is diameter and age correlated?

How is normal yield table derived from crown spread? from plots?

How can the yield table be dispensed with?

Explain a preliminary system of yield regulation for selection forests.

What data is needed?

Discuss complication of loss of numbers, normality, overcutting.

Compare this method with French system of 1883.

Enumerate essential distinctive characteristics of "American Regulation."

CHAPTER XII

THE PROBLEM OF SUSTAINED YIELD

The Ultimate Problem—Sustained Yield. Owing to the importance of preliminary and transition periods and the unavoidable disturbance of forest capital and postponement of the creation of a complete series of classes, the ultimate problem of regulation to secure that balance and increment in the forest which will permit of a permanent sustained cut, is necessarily obscured.

In the many-aged forest, as well as in that composed of even-aged stands, rotation is fixed upon, which is supposed to coincide with the average age of timber to be cut. Although the volume of the immature stands falling in the last third of this rotation is immaterial, the period required for them to grow to given sizes, and the area stocked by these young stands, is constant.

It finally determines whether or not a forest is being over-cut; i.e., working instead of mere surplus is being withdrawn, we must determine three things, all dependent on the rotation,—first, what the annual growth will be on a normally arranged forest stocked at no greater degree of density than the existing forest, for this is the gauge of whether capital is being increased; second, the amount of actual measureable (merchantable) capital required to produce this quantity annually, and its arrangement by age classes as to volume and area, in each age class; third, the comparison with actual forest as to volume and area, in existing age classes.

The crude assumptions in the illustration in § 137 as to growing stock and age classes are plainly insufficient to show these facts. An annual growth of 10 feet per year on cutover lands may or may not be obtained continuously. A growing stock of 4,000 bd. ft. per acre may or may not constitute the normal stock. The elasticity of the French conception of normal relations of growing stock between medium forest as $\frac{3}{8}$, and old forest as $\frac{5}{8}$ of the total merchantable volume, lies in the fact that it applies only to the form and proportion of the two broad age groups, and equally to all degrees of stocking. It may be the only practical conception to apply to such forests, yet if possible, owing to the importance of the cutting cycle and the greater difficulty of the problem, a more concrete idea of possible sustained empirical yield is desirable.

Allowed Cut, Empirical Yield Table and Normal Stock. This can be secured when it is possible to obtain an empirical yield table (by methods described in § 141) applicable directly to the degree of stocking in the forest. The French did not attempt.

With such a table, the allowed cut of the forest is at once indicated. It consists of the yield, at rotation age, of 1 acre $\times$ the $\frac{\text{area in the working circle}}{\text{rotation}}$

The yield equals the total growth of a forest of this density for one year, normally arranged as to age classes, or, its equivalent, the mean annual increment on one acre $\times$ total area.

On this basis, the normal growing stock can be computed, not by the method of approximating the residual growing stock below the size explained as being normal at 4,000 bd. ft. per acre, for instance, but from the table. An example of an empirical yield table is given below for Western Yellow Pine, Coconino National Forest:

TABLE 15. Empirical yield table of Western Yellow Pine reduced from normal factor 66.2%.

Age	Scribner Dec C. Log Rule.		Mean annual growth	
	Yield			
	Feet. B.M.		Feet. B.M.	
80	4,700		59	
90	6,220		69	
100	7,480		75	
110	8,610		78	
120	9,670		81	
130	10,660		82	
140	11,580		83	
150	12,510		83	
160	13,370		83	
170	14,300		84	
180	15,090		84	
190	15,950		84	
200	16,750		84	
210	17,540		84	
220	18,070		82	
230	18,270		79	
240	17,940		75	
250	17,280		69	
260	16,350		63	
270	15,360		57	
280	14,300		51	
290	13,170		45	
300	12,050		40	
310	10,920		35	
320	9,800		31	
330	8,670		26	
340	7,610		22	
350	6,420		18	
360	5,300		15	
370	4,100		11	

In § 135 the annual cut for the Coconino based on Von Mantel's assumption was found as 31,511 M ft.

Based on the assumption that the annual cut should equal the annual growth, the cut, for a rotation of 200 years and area of 509,087 acres at 84 bd. ft. per year mean annual growth, would be 42,763,308 bd. ft. annually.

The growing stock required to perpetuate this cut would be, not $\frac{i \times r}{2}$, w
would call for 4,276,330 M feet, but $\frac{(a + b + c + \dots + \frac{n}{2}) 10}{200} \times 509,087$
acres = $\frac{138,515 \times 10}{200} \times 509,087$ (6,925 bd. ft. per acre)

25,427 M, or approximately 80 per cent of that required by the formula
 $= \text{Gn}$.

is determination of the real basis for a growing stock which would
 etuate the rate of growth now possible and realized in the past from the
 n forests enables us, first, to measure the actual growing stock to dis-
 r whether there is a surplus or deficit, and second, prevents us from
 apting to reserve, as working capital, wood which is actually surplus.

**5. Comparison of Mean Annual Increment and Austrian Formula. Its
 ations.** The mean annual growth of a stand to maturity rather than
 ent growth per cent correctly gauges the increment for a stand which
 at since this cut takes, not the current increase from standing trees, but
 r total past growth, which is the mean annual growth times age of
 stand.

r the present stock exceeds or falls short of this normal growing stock,
 an indication that there is either a surplus caused by an excess of over-
 are timber, or a deficit caused by past cutting, fires or other destructive
 acies. It cannot mean that the indicated yield, or normal stock, is wrong
 e the actual past production of the forest itself has been taken as the
 s for calculating this growing stock.

follows then that the Austrian formula, when based upon the empirical
 d table to obtain the normal growing stock, and when the mean annual
 ement for the rotation age is used as the basis of increment, is an
 uctive check on the proper annual cut. The surplus, by our methods,
 ld in order to save further loss be removed in one cutting cycle if the
 r is fairly long. Cc, or at most 2 cc, becomes the period of regulation.

$$\text{Annual cut} = \text{mean annual increment} + \frac{\text{Ga} - \text{Empirical Gn}}{\text{cc or } 2 \text{ cc}}$$

plying this formula to the Coconino:

$$\begin{aligned} \text{Annual cut} &= 42,763 \text{ M} + \frac{3151147 \text{ M} - 3525427 \text{ M}}{100} \\ &= 42,763 \text{ M} - \frac{374280 \text{ M}}{100} \\ &= 39,020 \text{ M} \end{aligned}$$

ut applying the Austrian formula to current growth as in Munger's illustration, his
 ir normal growing stock is first calculated as

$$\text{Gn} = \left(\frac{\text{I} \times \text{cc}}{2} + \text{Reserve} \right) \times \text{area}.$$

ith total current annual increment in the forest, per acre, as 100 feet, and cc as 50
 s, reserve per acre 4,000 feet,

$$\begin{aligned} \text{Gn} &= \frac{100 \times 50}{2} + 400 \\ &= 6,500 \text{ feet per acre.} \end{aligned}$$

he actual growing stock is now 16,000 feet. Munger wants to cut 12,000 feet per
 on 4,000 acres or 48,000 M bd. ft. annually, on 200,000 acres, leaving the reserve of
 0 feet to grow to 9,000 feet in 50 years.

r the Austrian formula:

$$\begin{aligned} \text{Annual cut} &= 100 + \frac{16000 - 6500}{50} (\text{area}) \\ &= 290 \text{ bd. ft. per acre or } 58,000 \text{ M bd. ft. in the first cutting cycle which} \end{aligned}$$

is evidently excessive, due to the inclusion of growth in the formula which was included by Munger in the first cutting cycle. The Austrian formula is thus evidently inapplicable to this transition problem on the basis of current growth on cutover areas.

The undertaking of regulation requires a sufficient knowledge of growth to indicate a rotation. Upon this basis, and the conception of a uniform felling series for even-aged stands, the empirical normal growing stock may be compared with the actual forest in order to separate the forest capital from surplus or deficit and obtain an indication of the amount of the required annual cut.

The annual cut by any system of regulation will seek to remove an amount equal to the "interest" or growth, plus or minus an amount which will bring the capital either down or up to normal form within a reasonable period.

When the true form of a series of age classes is not obtainable, a relation based on the growth of trees and broad age groups can be constructed. This was done by the French in 1883, by which the surplus or deficit can be indicated as well as the growth. For our conditions, this relation should be based on the felling reserve and the influence of maturing crops of timber in determining the cut.

Whenever it is possible to determine this true form and volume of the empirical normal forest by means of an empirical yield table, and to base increment upon the mean annual growth from this table, the true relations between empirical increment and surplus or deficit in the actual forest caused by abnormal age class distribution can be found, and the annual cut approximated by the Austrian formula check. Without this data the Austrian formula is more accurate than Von Mantel's and if $cc = \frac{1}{2} r$ and "normal" stock is taken as $\frac{r \times i}{2}$ the two formulae will give identical results.

This pure volume check on regulation accomplishes in a rough approximate manner, what should be determined on a basis of definite knowledge of the forest, as soon as that knowledge is available.

The utility and value of the Austrian formula is dependent, then, not on the formula itself, which is merely the expression of a sound principle of regulation universally sought, but upon the determination of the three factors, actual increment, empirical "normal" stock required by this increment, and the actual stock on hand. The cutting cycle then enables the determination of the cut per year. No knowledge of the age classes in the forest is required, and this is just where the formula fails.

Every method of regulation seeks to establish this same result, but the differences between a practical plan and a formula check lie chiefly in recognition of the fact that abnormality in volume is caused by abnormality in distribution of the respective age classes. Only by securing this proper distribution of age classes can the true normal volume and sustained cut ever be secured. The growth actually laid on in the forest during a given cutting cycle is not the mean annual but the current growth, and this is dependent upon the age condition of these abnormally arranged age classes.

Being sound in theory, the Austrian formula *when based on facts* as determined

ed by growth studies, does surprisingly well, but it is better to deal with facts at first hand. In other words, since the regulation of the forest must be determined by the area, volume and current growth of the existing age classes, the determination of these areas, volumes, and the actual current growth with expected, will in turn indicate the area and actual volume of the actual cut best adapted to securing progress towards a normal forest.

56. Necessity for Data on Age Classes. In the system proposed for many-
aged forests, the present volume and actual current growth of the exploitable
of the maturing age classes were found as a prerequisite of fixing the cut.
for lack of data on areas, the yield for the entire rotation and the true con-
dition of abnormality of the forest could not be accurately obtained which
shows the progress toward normal forest and sustained yield.

In choosing a method of working out this problem of sustained yield the
cultural behavior of the species must decide. If the trees customarily
undergo a period of suppression in growth, the age of individual trees gives a
very unreliable index of the number of years required for an acre to produce a
given yield in wood.* But if the species is intolerant, we have two distinct
advantages; first, the individual trees which survive and form the final cut
are usually dominant throughout their life cycle and are seldom suppressed.
Second, in spite of fires and other agencies, the forest tends towards even-
aged groups, of varying size to be sure, but distinctly different from typical
many-aged stands which result from suppression and natural selection over
a long period of struggle.

57. A Method of Separation of Age Classes. The method to be described
is applicable to intolerant species growing in stands of all ages in original
forests. Since species susceptible to fire occur in even-aged stands and can
be measured by direct yield tables, while tolerant species such as hemlock
and spruce are subject to suppression, this method is especially applicable to
Western Yellow Pine, Southern Longleaf or Loblolly Pine and similar species,
and may have a wider application. For even in forests composed of tolerant
species, many-aged, and mixed, the interference of fire, insects and wind
constantly tends to produce groups of even age, and this fact can be taken
advantage of to secure data for a yield table based on age, which will serve
as a model or standard from which these essential relations of age and volume
per acre can be obtained even for all-aged stands. Owing to its great impor-
tance in future regulation, the method of securing and applying such a yield
table is given in detail. The species to which it was applied was Western
Yellow Pine, but the method should be applicable, with suitable modifications
in field technique, to nearly all our American forests of mixed age.

Essential Steps. The three steps in this regulation are:

- (a.) Securing the normal or standard yield table,
- (b.) Application to the forest to secure the empirical yield table and to
separate the forest into age classes by area and volume
- (c.) Regulation of the cut based on area, volume and prediction of
growth of these age classes, by use of this yield table.

Standard Yield Table. Selection of Plots. (a) Yield table. The standard method followed in securing plots. These plots are laid off in groups or stands whose appearance indicated that practically the entire stand is of a given *age class*, though not necessarily of *even age*. A curve of average height based on diameter should be determined for each plot or group of plots, preliminary to computing volume.*

Where trees evidently of an older or younger age class are included in the plot, crown space, or the proportional area occupied by such trees may if desired be deducted along with their volume to confine the results to a single broad age class.

Determining Age of Plots. Age of the plots is best determined by felling at least ten trees, selected to represent average volumes. But when the timber is very large, old, and is inaccessible to logging for the present, the felling is not only time consuming (increasing the cost of plot measurement by 300 per cent or more) but wasteful of timber, especially in the older stands. A substitute method of obtaining the age of a plot is as follows:

a'. A curve of growth in diameter must be obtained from numerous stump measurements on logged areas. This should show the *age* at B.H. outside bark for *average trees of given diameters*. It is necessary that these growth figures be obtained for trees of the same type and quality as the plots measured, else the conclusion regarding age of the plot will be in error.

b'. The diameter of the average tree in the plot must be determined. In reducing stands of uneven age to their equivalent for an even-aged stand, the standard practice is to determine the age of an even-aged stand which will yield a *volume equal* to that of the uneven-aged stand in question.** The basis of volume must be the volume of a tree and volume unit used in calculating growth. The first step in finding the tree of average diameter is to determine the tree or average volume from the total number of trees on the plot, and total volume.

But as height is a variable, and the tree of this volume may be a tall tree with smaller diameter, or a short tree with larger diameter, we must first obtain the average height of a tree of this average volume, for the plot in question. The curve of average height on diameter for the plot has already been made for computing the volume of the plot, hence is available.

With average height on diameter for the plot determined, there can be but one average diameter for a tree of a given volume on the plot. This is read from the curve of volume on diameter usually interpolated to 1/10 inch.

The age of a tree of this diameter from the growth curve is taken as the age of the stand on the plot.

Wherever site qualities can be separated, based on total heights of merchantable timber, and the curves of diameter growth obtained are coordinated with trees on the separate site qualities, this method has the double advantage of enabling the field crew to secure three times as many plots in a given time, and of basing the age of each plot upon a curve based on a large number of representative trees instead of but one or two trees which, on single plots in these uneven-aged stands may happen to be much older or younger than the real average desired. The stand not being truly even-aged, the advantage of felling single trees to determine age for the plot is much lessened, provided always that the growth data for the use of the alternative method is properly coordinated with the site.

158. Application of Yield Table to the Forest. (b.) Separation of age classes in the forest. The problem is twofold, first, to find a method by which the age classes of the forest may be separated, second, to determine actual average density or degree of stocking for the entire area.

Experience in former experimental attempts to solve this problem has shown the futility of trying to determine the area and volumes in different age classes on a large

* See § 129 and 130, *Forest Mensuration*, John Wiley & Sons, 1921.

** *Ibid.*, § 260.

of this character by mapping the crowns, or by any direct method. Instead, evidence must be placed directly upon the volume of the stand, and its direct division into age classes by aid of our knowledge of the number of trees in the stand and the size, diameter and age of average trees.

Stand Table. To obtain the number of trees in the age classes, the volume of the average tree and the total volume of the class, a stand table is required.

A stand table is best obtained during timber estimating by any method which provides for a table of diameters. In estimating, it is accepted that strips covering 10 per cent of a large area give a sufficiently accurate per cent of the total volume. The percentage principle applies as well to a stand table. If made to include the trees used in estimating, the resultant table should show the distribution of diameters in the stand, on a percentage basis, regardless of whether all or only a portion of the trees in the stand are tallied.

The total volume of the trees actually tallied in a stand table may be correlated with the volume of the forest or unit in one of two ways.

Area. 1. The area covered by the trees tallied is known. This enables one to reduce the table to a stand *per acre*, which is assumed to be average for the forest.

Volume. 2. The volume tallied is taken as the basis. In this case, the average volume per acre tallied need not coincide with that of the forest.

The relation in volume is found by comparing the total volume in the stand table with that of the forest. If 20 per cent has been tallied, the proportion is as 1 to 5. This is a more useful relation than area and more easily obtained.

Purpose and Application. (c.) The real purpose of the stand table is to serve as a basis for determining the *percentage* of volume in the different diameters or age classes of the large area or working group which it represents. If a stand table can be divided into groups representing age classes, and the volumes in these age classes ascertained, these volumes can be expressed in terms of per cent of total volume for the stand table and if this table is properly constructed and representative of the forest, these per cents will apply to the entire unit and will separate the total estimate of volume in the respective age classes. The steps then are:

Separate the volume in the stand table into volumes of given age classes.

Find the per cent of total volume which these age classes represent.

Apply these per cents to the total estimate to divide the forest into age classes.

9. Separation of Stand Table into Age Classes. The factors of the problem are: the average tree of each age class, and its diameter, volume of said tree, number of trees in each age class, in the stand table. When these factors are determined, the volume of each age class, its age and the area occupied can be determined and the results applied to the forest unit.

In any method, *only a few broad age classes should be separated* for the working group.

Diameter Groups. The simplest basis of division of the stand table is by diameter groups, assuming that the average age of a diameter class holds true for the trees in the class or will serve as a basis of volume separation (French method of 1883).

But the division of mature or merchantable timber into age classes based on diameter alone, actually runs counter to a law of growth of trees growing in stands. Diameter growth of individual trees is far more variable than height growth, being affected by density of the stand and the origin and dominance of the individual tree. For trees of a given age class, whether growing in even-aged stands or scattered through older stands, the dominant trees grow more rapidly and reach larger ultimate sizes before they die than do the intermediate, while the suppressed trees are much smaller in diameter than their age than the more vigorous trees.

Trees of a given diameter over a large area include always a range of ages, and this range becomes greater as the diameter of the class increases.*

Age Groups. If as few as three broad groups are made (corresponding with the

In the larger diameter classes the range of age may again diminish due to the fact that only dominant trees reach these sizes.

French system of two groups, plus a third overmature or decadent group), it may be possible to separate the stand on a basis of average age rather than diameter limit.

For Western Yellow Pine, the young, merchantable age class, below the exploitable age, or up to 150 years in a 200 year rotation, may be tallied separately by the color of bark and thus actually separated, as an age group, from the mature and veteran yellow pine timber. If this has not been done in general estimating, the stand at least will have to show separate tallies for blackjack, and the per cent relation obtained is applied to the total estimate.

Lacking this differentiation in appearance based on color of bark, the younger class will probably have to be separated by diameter. It is in the determination of average age for the groups that a flaw appears (ignored by the French as immaterial).

160. Average Age of Groups. To Determine Average Age of the Group. The procedure is identical with that described for determining the age of plots in constructing a yield table,

1. Determine total volume in the diameter group.
2. Get volume of average tree,
3. From table of volumes on diameter for type, get diameter of this average tree.
4. Look up age of said tree from growth curve based on diameter.

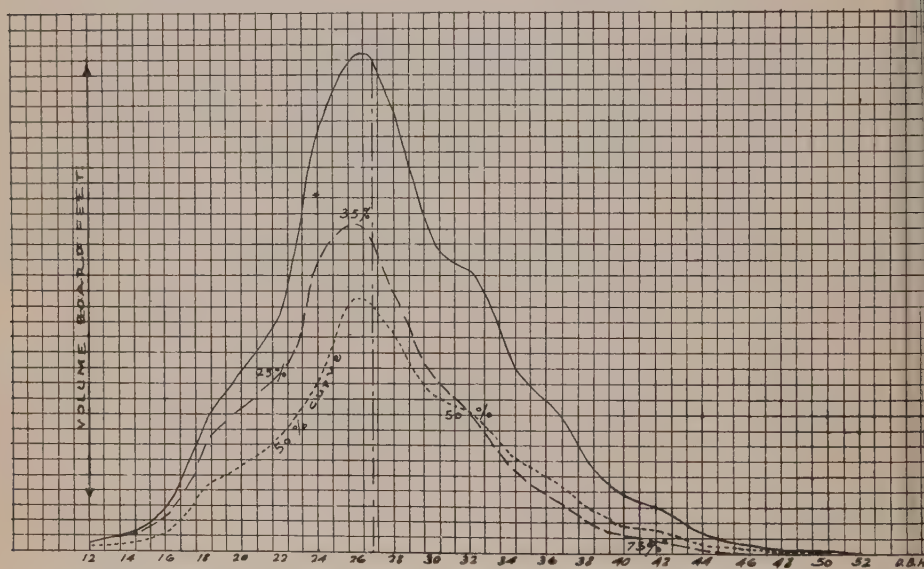


FIG. 7. Volume of Western Yellow Pine, Distributed by Diameter Classes, Coconino National Forest.

- Total Volume.
- - - - - Volume of Mature Class, Decreasing by 5% for each 2-inch Diameter Class.
- Volume of Mature Class, Taking 50% of each Diameter Class.
- . - . - . Division of Volumes into Mature and Veteran Classes, by Diameter Group, each Containing an Equal Volume.

Figure 7 illustrates three different methods of dividing the stand or group into age classes. The upper curve represents the volume actually occurring in each diameter class.

By the first method, it is considered that the trees which belong to the veteran class form an increasing per cent of each diameter class. This increase is taken in this illustration as 5 per cent beginning with 14 inches. The resultant volume of the veteran

parated from that of the remaining mature age class by the line——. This od was tried out on the Plumas National Forest in 1912, and described by ington Moore in Proceedings of Society of American Foresters, Vol. IX, No. 2, 216.

is method uses diameter as a basis, but endeavors to follow the known laws of eter growth by this cumbersome and impractical subdivision of each class.

e second method makes an arbitrary division, based on diameter classes, between ans and mature trees, and is illustrated by the vertical line-----. This is le of application, but departs widely from the laws of growth, throwing many ans in with the mature group, and vice versa.

ie third method is never used and is included only for purposes of comparison of lts. It is to divide each diameter group into equal volumes for veterans and for re, by the line——.

ie resulting average tree, taken from the stand table on which these curves are d, for each of the three methods resulted as follows:

Method used	Age class	Volume of average tree board feet	Diameter of average tree inches	Age of average tree years
Diameter Classes Subdivided				
	Veteran	837	27	302
	Mature	515	23.5	245
by Diameter Groups				
	Veteran	1,267	29.5	345
	Mature	393	21.5	214
of Equal Volumes				
	Veteran	609	24.5	261
	Mature	609	24.5	261

se results indicate, first, that by the method of dividing by diameter groups, the age volume and diameter of the older group is raised arbitrarily by the exclusion he slower growing smaller trees. When the average age is sought from a curve of meter based on age, the indicated age is incorrect and exceeds the normal age of group, so that it is necessary under these circumstances *to derive age from a curve of based directly on diameter.*

he reverse of this condition is shown by the purely theoretical division into groups equal volume, by which the resulting average tree and age of each group is equal. e true average age and volume evidently lies between these extremes. While the de basis of division adopted in the illustration is evidently incorrect in that it udes too great a portion of the total volume in the mature class and raises its age 245 years, yet evidently this method comes close to a division in which volume and of the average tree for each group correspond reasonably with the probable ditions whose determination is sought.

his method is impractical in application, since the determination of the correct per ts of each diameter class to take for each age group is difficult, and the computation glesome.

ased Directly on Age. But there is another and simpler way of solving this problem. e yield table is the best indication of the ages at which *stands* of the species approach turity and begin to retrograde. The forest is composed of a series of age classes h including several diameters. When this continuous series is to be combined into two groups, each group in turn embraces trees whose diameters overlap those in other group. By shifting the average age of either group, the number of separate classes included in both groups is changed, but there is no inherent difficulty in uping the total number of age classes in any desired combination provided the two ages are far enough apart to fall within separate groups.

It is possible, for instance, in a forest containing a definite number of trees, a given total volume, to select two trees of given volume, one for each of two groups. With these two volumes fixed, a definite number of trees will be required each group to make up both the total volume and total number of trees in the forest.

If falsely based on equal division of each diameter class, each group would take the total, and the average volume of each group would be equal to that for the stand. If based on division into 2 diameter groups the excess in normal size of veterans would require too few trees in the class, the remainder required to make the total being trees with the smaller average volume.

To approximate the actual conditions in the forest, which is the result desired, age be the starting point, since it is the basis sought. From the yield table select age indicated as most characteristic of each class required. The steps then are:

1. Age required for class.
2. Diameter of a tree of this age.
3. Average volume of a tree of this diameter.

If the number of trees required for each age class, in order to make up both the number and the total volume in the stand table, can now be found, the problem is solved.

The solution given below can be applied only to two groups. In the example given Western Yellow Pine, the younger group has already been separated by the appearance of the bark. The method then will accomplish the separation of the mature, exploitable portion of the timber in a forest, above a given diameter, into the groups representing decadent and vigorous trees. This is well worth doing. In forests already under management, in the second cutting cycle, the method will separate mature from the young merchantable group.

Formula. For this solution the full data for each separate diameter class in the stand table is *not needed*. A count of all trees tallied, and their total volume, will suffice. (It is assumed that Blackjack are tallied separately.)

Then

- x = number of mature trees.
- y = number of veteran trees.
- a = volume of an average mature tree.
- b = volume of an average veteran tree.

Evidently $ax + by$ = total volume of stand.

But $x + y$ = total number of trees in stand.

If this total is multiplied by the volume of the average mature or smaller tree, a , resultant volume $a(x + y)$ can be subtracted from the total volume of the stand, indicate the surplus over $a(x + y)$ in the forest, due to the fact that a certain number of the trees actually have the average volume b instead of a . The surplus contained one such tree is $b - a$ or the difference in volume between a veteran and a mature tree. By dividing the total surplus by the surplus of one tree ($b - a$) the number of trees is found which must contain an average volume of b instead of a , and the remainder the number of mature or a trees.

Let c = total number of trees
 d = total volume

Then $ax + by = d$
 $a(x + y) = ac$
 $(b - a)y = d - ac$
 $y = \frac{d - ac}{b - a}$
 $x = c - y$

Illustration from Coconino National Forest.

STAND TABLE

Age class	Trees	Volume	Per cent
Blackjack	43,084	5,931 M	18
Yellow Pine	44,423	27,042 M	82
		32,973 M	100

DIVISION OF YELLOW PINE INTO VETERANS AND MATURE

	Age*	Diameter B.H. inches**	Volume per tree Ft. B.M.***
Veterans	300	27	805
Mature	200	20.7	340
Blackjack	90	17	137

x = number of mature trees.

y = number of veterans.

$$340x + 805y = 27,042,800 \text{ ft. B. M.}$$

$$340x + 340y = 340 \times 44,423 \text{ or } 15,103,820 \text{ ft. B. M.}$$

$$465y = 11,938,780 \text{ ft. B. M.}$$

$$y = 25,677 \text{ trees.}$$

$$x = 18,746 \text{ trees.}$$

$$\text{Mature pine} = 6,373,640 \text{ ft. B. M.}$$

$$\text{Veterans} = 20,669,985 \text{ ft. B. M.}$$

$$\text{Total} = 27,043,625 \text{ ft. B. M.*}$$

PERCENT OF MATURE AGE CLASSES IN VIRGIN STANDS ONLY

Timber above 12 inches D.B.H.

	In yellow pine. Volume	In total stand. Volume
Mature	23.6%	19.4%
Veteran	76.4%	62.6%
Blackjack	....	18.0%

TOTAL STAND OF SAWTIMBER IN VIRGIN STANDS, DIVIDED INTO AGE CLASSES

Veterans	1,972,618 M
Mature	611,323 M
Blackjack	567,206 M
Total	3,151,147 M

s gives us the volume in each of three age classes, corresponding to a definite age. It is evident, by the method used, that should we decide to divide the into age classes based on an increased average age for veterans, the number of an trees in the forest would be reduced and of mature trees increased, which sides with the laws of growth operating in the forest. The age groups are come averages, and these averages may be altered by altering the basis, age, without luding an error in fact or misinterpreting the true conditions of the stand.

. **Immature Age Classes.** In discussing the factor of the empirical yield table

ata from yield table.

Data from table, Diameter Growth, Bulletin 101 (Page 20), T. S. Woolsey, Jr.

Data from table, Volume on Diameter.

error of 825 feet by neglecting decimals in obtaining volume per tree.

(§ 139), or actual density of the forest, it was shown that age and volume separate age classes in a forest must first be found, for owing to the difference which age of a stand makes in its normal volume, no possible comparison with actual or estimated stand in a forest can be attempted without age as a basis. By the method, the age of three classes, all that are needed, has been found.

But before determining the density factor and empirical yield table (by the method described in § 141), a further analysis of the forest is necessary, to bring out the importance of the role which reproduction and timber below merchantable sizes play in any scheme of permanent regulation of yield.

Effect on Density of Stand. The density of a given forest is determined by three factors; first, the age classes, themselves, as shown; second, the actual degree of stocking or occupation of the site by the merchantable stand compared to full stocking (to be determined); third, the proportion of the total area occupied by age classes below merchantable sizes.

A forest composed of trees and groups of all ages intermingled may have 50 per cent of its area occupied by merchantable timber. If the remaining 50 per cent is stocked with young or unmerchantable sizes the forest may have an actual density of 100 per cent. But unless it is possible to ascertain the area so stocked with young timber and deduct it, the 100 per cent stocking is not apparent in the mature stand. The average stand per acre of merchantable timber of most forests is far below the standard, the average acres of mature timber and should normally be less than half of this (See yield table for $\frac{1}{2}$ r years.)

For computing the future yield of these mature classes, there are two alternative methods either to assume, e.g., that 100 per cent of the area is occupied by mature age classes with a density of 50 per cent, a yield of $\frac{1}{2}$ the full yield per acre from the yield table, or else, to determine that but 50 per cent of the area is stocked with merchantable age classes but that the yield on this area will be 100 per cent of or equal to that of the yield table. In the even-aged form of forest the latter condition is evident, and is equally true of the many-aged form and should be so treated. The total future yield of these merchantable age classes will be the same in either case, but the actual density of stocking is absolutely different.

So much for the forest which is fully stocked. In the actual or partially stocked forest the same relations exist. Assuming that one half of the area is reproduced to unmerchantable, young ages, and that the merchantable timber, in quantity, by age class is but 60 per cent of a full yield; this merchantable timber may be considered as occupying 30 per cent of the area with a yield 100 per cent of that of the yield table. If the immature timber is disregarded, the mature stand if figured either way will have the same volume in future yield. Its actual volume and yield is not changed. Age and density are reciprocal factors.

$$.50 \times 60\% = .30 \times 100\% \text{ of the standard yields.}$$

For regulation extending beyond the first cutting cycle, it is important to know what the immature age classes will yield. This yield will be largely determined by the number of seedlings established, but by the area restocked in acres. Yields are based on area, not on single trees.

Effect on First Cutting Cycle. If in the forest survey, this principle is recognized it will be possible to note the percentage of total area which is covered by young timber not under suppression, and having good chances for survival, just as separate areas are mapped in even-aged young stands. The more accurately this final result, i.e., the area ultimately stocked with timber by this reproduction, is predicted, the more accurate will be the prediction of the growth for the period when this young timber matures. On the other hand, quite a large error in this determination will not affect in any way the possible yields obtainable or predicted for the timber now of merchantable size. What it will do is to give a false or erroneous idea of the possible total yield and the subsequent length of cutting cycle to be assigned during the rotation to this young timber, and hence to influence erroneously the length of the first cutting cycle required to remove the timber now mature.

her reason in favor of determining the area restocked with young timber is this area is subtracted before computing the density of stocking of the mature timber. This latter density tends to approach normal and be indicative of the *actual* yield per acre obtainable, while if *not* subtracted these yields are evidently much too low. If the work is carefully done and the maximum area of young growth is obtained and the stocking or reproduction is plentiful, the density factor obtained for mature timber may be applied not merely to these mature stands, but to the *young* as well, to assure a conservative prediction of future yields.

The relations are illustrated below:

Density of Stand, or Reduction Per Cent. To determine this average density or reduction per cent, in the illustration, § 161, the area occupied by seedlings and saplings, reproduction, and by poles, is to be first deducted from the net area, 438,423 acres, not yet cut over.

Based on data obtained in the forest survey, the figure 25 per cent was adopted as representing the area within the working circle which is reproduced to seedlings and saplings; 25 per cent of 438,423 acres is 109,806 acres. The net area occupied by poles over 12 inches was then 328,617 acres.

As to poles, 6 to 12 inches in diameter, by data obtained from plots in normal or fully stocked stands averaged 88 poles per acre. On 7,034 acres tallied in preparing the yield table for the forest, the average number of poles 6 to 12 inches was 4.9. This is $\frac{4.9}{88}$ or 5.5 per cent of the total area stocked with poles at rate of 88 per acre, or 39,121 acres, leaving 303,775 acres net for timber over 12 inches.

The Prediction of Actual or Empirical Yields for the Forest. *Density of Stand, 12" and Over.* Applying the principle described in § 161 we get, for the available timber,

Class	Age Years	Yield per acre "Normal" ft. B.M.	Acreage required if normally stocked (x)	Per cent total net area, 12" only
Jack-jack	90	9,400	60,341	31.3
Mature	200	25,300	24,163	12.5
Veterans	300	18,200	108,385	56.2
Total "normally stocked" area			192,889	100.0

In the density of mature age classes 12" and over is $\frac{192,889}{303,775}$ or 63.5 per cent.

Since the density of the timber above 12" is computed on the basis of 63.5 per cent normal, it will be convenient to compute the density of the pole class 6" to 12" on the same basis instead of as normal density, since in the former case, the corrected yield table can then be applied to all the age classes including poles and saplings. Since the area of seedlings has been established on the basis of a stand which will produce a mature crop of average density, the assumption of the same yield for seedlings is conservative, rather than "normal" density.

Adding the normally stocked pole area, 24,842 acres, to the total *actual* area for poles 12" and over, the total *actual* area inclusive of poles is found, as 328,617 acres.

If poles are computed at 63.5 density, poles would occupy 39,121 acres instead of 24,842 acres, giving an overlapping or surplus area to adjust of 14,279 acres.

$$\text{Ratio of density} = 63.5 \frac{328,617 + 14,279}{328,617}$$

$$= 63.5 \times 1.0422 \text{ or } 66.2 \text{ (actually } 66.18)$$

0.662 is the true density factor for the entire accessible area of yellow pine, the factor per cent to apply to the yields given in the "normal" or standard yield table.

Found by dividing stand (§ 161) by yield of one acre "normal" from yield table given age of stand.

If the area occupied by poles had been estimated on the basis of fully stocked correction would have been necessary as before to reduce poles to empirical data. Otherwise a "normal" yield per acre would be assumed for these classes at maturity. The above plan seems preferable.

Area Occupied by Age Classes. From ratio $\frac{100}{66.2}$ (True ratio is 66.18, error 260 adjusted.)

AREA OF AGE CLASSES				
Class	"Normal" area acres	Actual area acres	Per cent of 438,423 acres	Age Years
Poles	24,842	37,486	8.5	50
Blackjack	60,341	91,072	20.8	100
Mature	24,163	36,469	8.3	200
Veterans	108,385	163,590	37.4	300
Total	217,731	328,617	75.0	
Reproduction		109,806	25.0	20
Total in forest working group		438,423	100.0	

164. **Application to Group Selection Forests.** *Relation of Cutting Cycle to Area Cut Over Already.* Nothing illustrates so well the interdependence of area and volume in regulation as the relation of the area already cut over in a virgin forest, to the cutting cycle.

Clear cut and ruined areas requiring restocking cannot be included in regulation for the first rotation at all. But areas cut by conservative methods or areas in which restocking has taken place after former cuttings, are included.

To determine the length of the first cutting cycle, which is to compute the first cut of virgin timber, the total area may be reduced by the area clear cut or destroyed, but on the area cut under conservative methods is better, if the process has not gone too far, to compute the proportion per cent of the area which has been already cut as part of this first or transition cutting cycle, which has already elapsed. Where the cycle is $\frac{1}{2}$ r and per cent of the original stand cut is proportional to this cutting cycle, each acre cut over in logging is equivalent to but $\frac{1}{2}$ an acre actually clear, but to one full superficial acre for the cutting cycle itself. An acre cut clear is equivalent not merely to one acre cut over in the first cycle, if reproduction and young timber are destroyed, to one acre in the second and subsequent cycles as well, which would thus have their yields reduced. Hence the elimination of such areas in regulation during the first rotation.

Illustration. Coconino. Areas:

Virgin Timber	438,423 acres
Cut over	116,137 acres
Total	554,560 acres

the area cut over, there is

Cut clear	45,473 acres
Cut, leaving seed trees	8,208
Cut by Forest Service marking rules	62,456
Area conservatively cut	70,664
Total	116,137 acres

the area of 70,664 acres, a second cut can be obtained in $\frac{1}{2}$ r years. This is borne out by the per cent of area theoretically cut over as shown by the area of each class in the remaining stand.

50% cut will take, approximately

Veterans	100% = 37.4% of acre
Mature	90% = 7.5%
Total	45% of area

only $\frac{1}{2}$. Then this area if included as part of the unit, gives a total of 509,087 and an area cut over, in the first cycle, of 13.9 per cent equivalent to 14 years, reduced working circle.

Including the clear cut area in a total of 554,560 acres, the per cent of area cut for first cycle is 21 per cent or 21 years, and for the second cycle, 8 per cent or 13, a total of 29 years cut, equivalent to 15 per cent of the total area.

The total amount cut from the forest has been 593,621 M bd. ft. On the basis of 84 mean annual growth on 554,560 acres, this is equivalent to 13 years' growth. Conclusion is, that a conservative reduction of 10 years can be made in the length of first cutting cycle as having been already cut, and by reducing the area to 509,087 a period of 90 years should be allowed to complete the cut, with the assumption that 10 years' growth has taken place on the areas first cut over.

In this cycle of 90 years, the cut can be calculated based upon the actual age classes cut, by volume, growth and area.

Coordination of Cutting Cycle with Area and Volume of Existing Age Classes. It remains one problem in calculating growth. The progression or change represented, on the one hand by growth, and on the other by cutting, when it extends over a period of 50 to 100 years affects the percentage of present or existing age classes cut, respectively. When the volume per cent cut, as 80 per cent, coincides with the volume of age classes, as veterans plus mature, it is best to assume, as do the French, that cutting actually removes these classes completely. The volume left as seed trees is balanced against an equal volume cut from a younger class.

In the cut for cc years will be the present volume plus $\frac{1}{2}$ the growth of these classes, plus the volume of the timber falling, by age or size, in the period $\frac{1}{2}$ cc years with half its growth for cc years. To get the $\frac{1}{2}$ growth over so long a period, it is better to take the yield of one acre at $\frac{1}{2}$ the cutting period than $\frac{1}{2}$ the difference in yield at beginning and end of period. The difference in results is shown below.

Veterans, at 300 years =	12,050 ft.
at 390 years =	1,600 ft.
average =	6,825 ft.

Yield at 345 years = 7,015 ft.

Difference in yield, by second method, + 190 ft. per acre or 2.7%.

The maturing class, since its age limits coincide with $\frac{1}{2}$ the cutting cycle, may be calculated on the basis that the entire area of the next class covering cc years matures,

$\frac{1}{2}$ is cut, and the average age of the stands cut is the present age plus $\frac{1}{2}$ of the cycle, thus giving $\frac{1}{4}$ the "growth" on the total maturing stand.

But when the first cut takes only a part of an age class, say 90 per cent of the timber class, it is a question as to whether we shall assume that the 10 per cent remaining shall be carried through to the end of the cutting cycle—which it would not in practice—or our basis of calculation revised during the period to conform with actual practice of marking.

The best plan is probably to add the 10 per cent of mature timber to the area of residual growing stock where it belongs, and then in turn to deduct an equal area of the maturing Blackjack class which usually constitutes the residual growing stock, to be held over for the following cutting cycle, instead of figuring the entire class entering the exploitable age class in this cycle. This is the same principle as the diameter limit (§ 144).

On this basis the cut for the first 90 years will be,

Exploitable class:

Age class	Age	Average age when cut	Yield per acre. ft.	Per cent of total area to be cut	Area, acres	Total
Veterans	300	345	7,015	100	163,590	1,147,172
Mature	200	245	17,610	90	32,823	578,125
						1,725,297

Maturing crop:

	Age	Average age when cut	Yield per acre, bd. ft. when cut	Per cent of total area to be cut	Area, acres	Total
Mature	200	245	17,600	10	3,646	64,423
Blackjack	100	145	12,045	96*	87,423	1,053,127
						1,117,550

$\frac{1}{2}$ cut = 563,608 M

Total cut for cutting cycle

2,289,204 M bd. ft.

Annual cut for 90 years

25,435 M bd. ft.

166. Comparison of Annual Cut by Methods of Regulation Proposed. A comparison of results may now be made, for the different methods of regulation proposed.

Accepting a 100 year cutting cycle reduced to 90 years by previous cut for the removal of the first or original growth, and a cut of 80 per cent of the merchantable stand above 12 inches, as scaled in board feet, Scribner's Dec. C. Rule, we get, for a growing stock of 3,151,147 M ft.:

By French method of 1883,

Annual cut = $\frac{.80 \times Ga}{90} = 28,054$ M. This assumes a balance of growth and decadence.

By Von Mantel's formula,

Annual cut = $\frac{Ga}{.5r} = 31,511$ M. This result must be rejected as based on false assumptions of normality.

*91,072 — 3,646 acres = 4 per cent of the Blackjack area, equivalent to 10 per cent of the smaller area of mature timber.

y cutting the mean empirical annual growth,

Annual cut = 84 bd. ft. $\times$ 509,087 acres = 42,763 M. This fails to recognize the presence of overmature, stagnant surplus.

y Austrian formula,

building up the stock to 3,525,427 M in 90 years,

Annual cut = 38,605 M.

y cutting the actual volume, plus growth, to 80 per cent and creating a reserve,

Annual cut = 25,435 M.

The agreement between the latter figure and the first, based on the original French method of 1883 which ignores growth and a felling reserve, and the difference of 13,170 M ft. in the annual cut as indicated by the Austrian formula are very significant, for upon these data rest the proof of the fact that the Austrian formula is not applicable to virgin forests in America if sustained yield is sought. Theoretically, the cut by this formula is nearly 50 per cent higher than it should be by the best analysis of facts that we can get. This won't do. Evidently Munger's assumption of a balance between growth and decadence, and the original French plan of ignoring growth, give results much closer to the facts. The explanation lies in the fact that the Austrian formula *assumes* that the forest is already under regulation and requires producing an annual increment on all stands. It does not take into account natural loss from decadence, which *must* be incurred previous to cutting, and on all stands, and in a long cutting cycle is a serious factor.

In the present instance, the loss on 163,590 acres of veteran timber is the difference between the yield of one acre at 300 and 345 years, or half the difference, multiplied by the area. This is,

$$12,050 - 7,015 = 5,035 \text{ bd. ft. per acre}$$

$$5,035 \times 163,590 = 823,675 \text{ M bd. ft. in 90 years}$$

This represents a loss of 9,152 M ft. per year. Added to the indicated cut, by the last method, it would total 34,587 M bd. ft. or but 4,018 M bd. ft. per year less than the cut indicated by the Austrian formula. The formula fails because it is not based on actual conditions. The simple formula used by Munger is approximately correct because it does coincide with actual conditions.

What is needed is a method by which the *actual conditions and not the formula determine the cut*. The method proposed, whether it is applied by classes of diameter classes and growth as in many-aged forests, or age classes, as in the above illustration, is based on the conditions in the forest, and makes no erroneous assumptions as to either form or arrangement of age classes, or growth. In this illustration, the growth reaching maturity in the 90 year cycle fails to balance the decadence or loss by 78,030 M bd. ft. or 867 M bd. ft. per year. In a forest composed largely of younger timber the reverse would be true.

Summary of Basic Principles. To sum up:

The basis of applied regulation in America as elsewhere must be the determination of growth in the forest, for the average empirical stocking, and the

division of the forest into age classes by volume and area either by diameter classes or directly on age.

With a long cutting cycle and correspondingly large felling reserve required by our economic conditions of transition from virgin to regulated forest, the annual cut during the cutting cycle will be found by dividing by the sum of:

1. The volume *now exploitable* plus $\frac{1}{2}$ the growth during the cycle—computed as, the volume which the exploitable timber will have in $\frac{1}{2}$ cycle.
2. Plus $\frac{1}{2}$ the present volume of the timber which will mature within the cycle, increased by $\frac{1}{2}$ of the growth on the volume cut, which is $\frac{1}{4}$ of growth on this total volume.

The felling reserve will be the volume, at end of cutting cycle, of all stands which have matured within the cycle on areas after cutting is past on the area. This will be equivalent to the volume, at end of cycle, of stands ranging in age from $r - cc$ to $r - 2cc$ years. This basis is applicable to all forms of forest whether even- or many-aged.

The analysis of the forest into age classes, the determination of immature age classes by area and the obtaining of an empirical yield curve will make possible the further regulation of the cut covering the second cutting cycle and remainder of the rotation.

The balancing of the cut between the first and second cutting cycle, as permitted by silvicultural conditions, means carrying over the surplus and can be accomplished by reducing the per cent of cut in first cycle equivalent to raising the diameter limit and age, or vice versa.

168. Factors Indicating a Shortening of the Cutting Cycle. *Illustration.* The loss by decadence of 25 per cent of the total available timber, or 33 per cent of the cut actually realized, as shown above, is sufficiently serious to raise a question as to whether the cutting cycle in virgin forest should be prolonged to $\frac{1}{2}r$ even if the per cent of the stand which must be cut indicates this procedure. The possibility of shortening the cycle, say to $\frac{1}{3}r$, depends upon the data on growth obtained for cutover lands, and the reliability of conclusions drawn as to the behavior of the forest under management. Assuming, in the above case, that growth on cutover lands, *per acre of timber* increases, from 84 bd. ft. to 105 bd. ft. per year, or 131 per cent, this would permit of shortening the cutting cycle to 80 years which at 105 bd. ft. per year would yield 8,400 bd. ft. as before. Then, if 10 years cut has already been made, a cutting cycle of 70 years would be indicated instead of 90 years. On this basis, the annual cut by the three methods discussed would be:

1. By French Method,

$$\text{Annual cut} = \frac{.80 Ga}{70} = 36013 M.$$

2. By Austrian formula,

$$\text{Annual cut} = 42,763 M + \frac{3151147 M - 3525427 M}{70} = 37416 M$$

3. By American Method,

$$\text{Annual cut} = 34927 M.$$

latter figures are obtained as follows:

Exploitable class.

Class	Age	Average age when cut	Yield per acre	Area	Total cut
Ans	300	335	8,140	163,590	1,331,622 M
e	200	335	18,105	32,823	594,224 M
					1,925,846 M

Maturing group.

	Age	Average age when cut	Yield per acre when cut	Area	Total cut
e	200	235	18,105	3,646	66,010 M
jack	100	135	11,120	87,423	972,143 M
					1,038,153 M
$\frac{1}{2}$ to be cut			519,076		
Total for cutting cycle				2,444,922 M	
Annual cut				34,927 M	

For this reduced cycle, the loss from decadence is 639,636 M bd. ft. or 3,910 bd. ft. per acre on 163,590 acres, giving a total, with the cut, of 3,084,458 M bd. ft. This loss is 18.9 M bd. ft. per year—nearly the same annual loss as before, but less by 20 years, or 4,039 M bd. ft. on account of the shortened cycle. The total cut is nearly the same, being greater by 155,718 M for the shorter cycle. The real difference lies in the rapid cutting, giving an annual increase in the cut, of 9,492 M ft. or over 37 per

cent. This increased annual cut is justified only by a showing that growth on over lands will permit the shortening of the cycle without interrupting continuity of the yield, the importance of the point originally made, that with studies on cutover land are the beginning of regulation, is again emphasized. Knowing the proper length of cycle, the disposal of the virgin forest even in the absence of data on decadence may usually be regulated on a conservative basis by ignoring both growth and decadence.

- Quiz.** Why is sustained yield the ultimate problem?
 What are the limitations of the Austrian formula? Its good points?
 In many-aged stands how can yield tables be constructed?
 How can the yield table be applied to the forest?
 How can the stand table be separated into age classes and average age determined?
 How should immature age classes be treated?
 What must be done to secure "reduction per cent"?
 How is the area occupied by age classes secured?
 How is the cutting cycle coördinated with area and volume of existing age classes?
 Explain how the prediction of actual or empirical yields is done.
 In the case cited in § 166 which method indicates the largest yield? Why?
 Which two methods give similar results? Why?
 What are the basic principles of the American Method?
 With a long felling cycle how can the annual cut be calculated?
 What will the felling reserve be?
 Discuss the relative evils of loss through decadence as balanced by interruption of

CHAPTER XIII

REGULATION OF FORESTS COMPOSED OF EVEN-AGED STANDS

170. Relation of Cutting Cycle to Distribution of Age Classes in Working Group. The same principles apply to the regulation of forests composed of even-aged stands, as to many-aged, or group selection forests. The method of cutting adopted will determine the future form of the forests. Clear cutting with artificial reproduction simply means a 100 per cent cut, and a cutting cycle equal to r years, unless modified by the mixture of young stands on the general cutting area, forming several series of age classes as explained in § 116, when cutting cycles of less than r are actually practiced. In this case, while each acre is cut but once in rotation, the logging operations return to the logging unit to cut the successively maturing stands at shorter intervals. If this were not so, at the end of the first or transition rotation, these stands would reach ages ranging from r to $2r$ years before they were all cut on the final logging unit.

Just because a stand is even-aged now, it need not be clear cut. For instance in the Lodgepole pine forests on the Deerlodge National Forest in Montana and elsewhere, a long period of experimental cutting evolved a standard of marking which removed not 100 per cent but only 64 per cent of the stands which had reached exploitable size, leaving the other 36 per cent to put on growth. This process, continued, will break up the even-aged stands and bring on a group form. It will also increase* the yield of an acre of large sized material and the total yield of wood. It introduces the factor of thinnings into the question of yields.

171. Similarity of Problem with that of Many-aged Forms. The problem of regulating the even-aged form of forests should be approached in the same way as shown for many-aged forms. The first decision should be to determine the length of the cutting cycle which is required to grow the second cut, basing this on the maturing of younger age classes. In even-aged stands the second cut will include the remainder of the mature timber in the stands which have been cut over in the first cutting cycle (the 34 per cent in the illustration); plus the stands, now immature, which will reach maturity within the second cycle, and which, in this form of forest are on separate areas, where in the many-aged forest they are mixed with the mature timber.

It will probably be impossible to return to cut again even for thinning or improvement cuttings, in stands once cut over until all the remaining exploitable stands of overmature growth have been cut over once. The limitations of logging, as expressed by the cutting cycle, will prevent it.

172. Application to Eastern Mixed Hardwoods. For lack of analysis of the separation of the forest into its respective age classes, the application

* Subject to losses from windfall, etc., which will probably be excessive. T. S. W.

system in Eastern hardwoods at present is being based on the assumption the forest can be divided into even-aged stands, which will be clear cut. They are classed or allotted according as their average age is veteran, mature, or young merchantable. The periods favored in the Appalachian forests are 20 years in length. The stands in the oldest class are roughly assumed to be clean, and to furnish the annual cut for the next period. (See data Harvard Forest in appendix B.) The amount of the annual cut is based on the first plan proposed, corresponding with the French System of 1883 neglecting both growth and decadence.

Regulation on this basis is by the allotment principle. The areas regulated are small and the period of 20 years may not coincide with the cutting cycle, which may be much less, in case transportation is well organized. Or the stand may be composed of such large and irregular blocks of different ages on account of past cuttings that no regular cutting cycle or felling series can possibly be hoped for in this rotation. If, for instance, all the over-mature trees in a working group were located on one logging unit, and it was decided to remove it in 20 years, the cutting within this period would not touch the remainder of the logging units. If each of the remaining logging units were also comparatively even-aged so that the major logging operations were concentrated in them successively, during the entire rotation, then the cutting cycle as far as there can be said to be one, is coincident with the rotation. The creation of such large areas of forest composed of a single age group is one of the evil results of our unavoidable former system of extensive logging operations conducted without thought for the future of the forest as productive property. One of the main objects of regulation on such matted and mangled forests should be to plan as soon as possible for the adoption of a cutting cycle of reasonable shortness, which will permit of logging in every unit once during the cycle, and will thus create a number of series of age classes in each unit instead of one or two only.

Just as, in the West, a cycle of $\frac{1}{3}$ to $\frac{1}{2}$ century may be forced on us by inaccessibility (and the necessity for extensive railroad logging operations), thus forcing the component age groups on any one area to 2 or 3, so the unregulated exploitation of private areas has done the same thing in part on the Western forests which the government is now about to attempt to put under regulation for sustained yield. If we stop with the assumption that when stands are in reality composed of several ages, we must, for the sake of simplicity, assume them to be of even age and, because it is apparently difficult to know how to calculate the possible cut under a system of partial logging, we assume that the cut will be clear, then the outward form or model of our regulation will tend, not towards the actual creation of these several series in each unit, but towards their further elimination; either that or there will be no real coördination between the calculated cut and cutting cycle, and the distribution of this cut by area and by per cent of the stands concerned.

The argument here is not against the adoption of some plan of regulating the annual cut, which should be done on whatever basis is possible, pending determination of the true condition of the age classes in the forest. It

is merely intended to point out the tendency to adopt the simplest concept of regulation, that of a single series of even-aged stands with $cc = 1$, possibly a little more study of the data at hand would permit of a basis in harmony with the true state of the forest, and with the ultimate required for best silvicultural results. If Appalachian hardwood forests to be transposed by clear cutting into even-aged stands, the assumption even-aged groups now tends in the right direction—but *even then*, the failure to recognize more than *one* of these groups to a logging unit tends to use and perpetuate the *large cutting area* which characterizes the *long cutting*. An analysis of the forest into 2, 3 or 4 age classes on *each logging unit* is a great improvement over the neglect of these subdivisions by the process of lumping off the age of the whole unit.

Any plan of regulation is better than none—but the initial plan, admittedly in the absence of sufficient data, should as soon as possible lead to a plan based on accurate knowledge. Sometimes this additional plan may be expensive to secure—but in the experience of the writer this is so in the case provided the object or character of the data needed is understood and the methods of securing it are well thought out. The expense of comparing the yield table, stand table and growth data for the Coconino Yellow Pine working plan was trivial compared with the value of the information secured.

173. Prediction of Yields of Mixed Hardwoods. As long as investigators are tied to the fetish of mathematical accuracy in the interpretation of the play of living forces, whose results can only be mathematically ascertained *after they have occurred*, just so long will we be forced to the other extreme of adopting grossly inaccurate makeshifts in regulation of yield for lack of data of *approximate* accuracy which *can* be obtained and will vastly increase the certainty of our predictions, and management. The prediction of yield in mixed hardwood forests has for many years been considered an insoluble problem. No problem is insoluble provided the methods used are in harmony with the known laws governing the growth of the forests under investigation and provided the allowable margin of error is not set so small as to be out of harmony with the purposes of the prediction. All predictions of growth for long periods are subject to correction based on *actual growth* (see Gurnaud method § 83) after shorter periods have elapsed, hence we insist that they must be correct in the first place or else unserviceable. A little common sense is needed in tackling the problems of predicting growth in mixed forests.

This is a discussion of regulation, not of growth studies—yet there can be no permanent regulation without growth studies. Where several species exist together, they may grow at different rates. What is needed for regulation is the total net growth on an acre in board feet or other units (board feet would be more desirable as a permanent basis)—not the growth of separate species. It is necessary to know something of the relation of species to each other, their survival and dominance and the per cent of each in the average stand to get closer to the total production per acre, but the stand table shows this composition of the stand, and the growth study shows

based on silvicultural knowledge of relations of species. Composite yield is while lacking the apparent reliability and superficial accuracy of those for pure stands are perfectly practical for the present when based on qualities, and described as to average contents. Undoubtedly the best is to obtain *yields per acre* rather than to depend upon growth of individual trees in diameter as described for many-aged forests, since the former is based on *results* of growth on an area basis, while the latter takes account of forces outside the individual tree measured, hence fails to add the loss or suppression in the stand (and losses through competition between species).

4. Correlation of Regulation with Methods Proposed. Assuming that standard "cove type" yield table has been constructed which gives the *average yields* per acre of this type at different ages, the problem of regulation lists,

- (1.) In separating the forest into component age classes,
 - (2.) In determining the reduction per cent to apply to these age classes in order to predict the yield with the aid of the yield table.
- For the present the whole question of growth and future regulation is postponed by assuming the allotment plan with no growth, for cutting the mature timber.

The measures which are possible are:

An estimate, by area, of the young timber, either by maps, or by per cent, in as many age groups as is feasible or necessary, discounting for suppression to get net area of survival as nearly as possible.

Separation of net remaining area of mature timber into 2 or 3 age classes based on:

- (a.) Mapped areas, where the form of forest permits it and average yield can be obtained for each area.
- (b.) Diameter groups, when the first method is impossible; and correlation of age of these groups with age in the yield table by use of the ratio of average diameter in each case, or,
- (c.) Further improvement on b by substituting the age of the average tree and its volume as a means of dividing the stand into 2 age groups as described in § 160. In applying this principle to mixed forests, the same method by which the average ages of plots for the yield table was determined may be used to get the age of the tree of average volume in the forest.

The one requisite needed for the application of any of the methods dependent on the average tree for age, is a curve of growth based on diameter, which can be accepted as an average or representative curve for the type, or mixture. It will be said that with several species this is impossible. The answer is again that absolute mathematical accuracy is impossible for any method of determining an average unless all the elements are measured. The average, in forest mensuration, is used to *avoid the need* of complete measurements, and is not the result of total measurements. An average growth rate for several species does not presuppose that every tree in the forest must be measured for growth to insure correctness. If curves or growth showing age based on diameter for several species are weighted by

the average per cent of species in the type as shown by the stand table resultant curve will suffice for the purposes intended. Always bear in mind that forest mensuration is not exact mathematics; judgment in the use of the figures must decide the final answer.

Growth studies, either in the original stand or on cutover land, depend as much upon the stand table or growing stock, as upon the growth of the individual trees in the stand, hence the stand table is the first essential step in making any kind of a growth study of the forest as a whole, distinguished from standard plots or sample trees. It is the growth of the forest that we must have in order to regulate it, and it is the failure of investigators to devise simple means of coördinating growth studies with the average stand in the forest which has discredited the utility of growth studies and prevented their proper application.

175. Coördination of Regulation with the Silvicultural Practice. Once a forest is separated into age classes by volume and area, it is no longer necessary to make false generalizations as to the per cent of each stand to cut. In the group selection type described under Western Yellow Pine, the per cent of the stand cut on the average acre can be coördinated easily with the age classes present and as these classes are mixed together, the assumption of a clear cut of each age class, or the removal of part of any age class, or the reservation of the remainder as part of the residual growing stock, introduces no appreciable error in calculation.

Where stands actually of even age are not cut clear but are culled, the initial problem of separating the areas of these stands and the calculation of growth is so simple that there is no reason why this growth data should not be coördinated with the actual silvicultural practice.

176. Illustration for Lodgepole Pine. For example, if lodgepole pine should be cut on a rotation of 140 years, we need a yield table with reduction factor for the average stocking of the forest, and a table of areas, volumes, and ages of the age classes. The cutting cycle may then be fixed at say 40 years. This may be based on the fact that at least 70 per cent of the area is covered by timber below 100 years old, a satisfactory percentage of which will mature in this period. If timber approaching maturity is scarce, the cycle may be prolonged and vice versa. Due regard can be shown to the necessity of carrying over a surplus of overmature timber, but this also is attained by prolonging the cutting cycle rather than by raising the diameter limit. Increasing the per cent of each stand to be left in the first cut—factors which are more or less fixed by silvicultural and logging conditions.

Following the principles laid down for the transition cutting cycle (par. 138), the stands which will represent the cut in the first cycle will embrace all whose ages are above 100 years, or from 100 years up, including the surplus of overmature timber. The growth on these stands is found by determining the yield which they will have at 100 years, or 20 years, by taking the yield for each age class, at the increased age thus fixed, from the yield table. But to successfully transform the forest, the minimum age of stands to be cut as the operations progress over the area must be set at 100 years, or 120 years.

To take a concrete case for Lodgepole pine on the Bernice working circle, Deer National Forest,* where the rotation is 140 years:

* Bulletin 234, U. S. Dept. of Agriculture, page 35; yield table, Bul. 154, U. S. Dept. of Agriculture, page 32. At 140 years, normal yield is 15,840 bd. ft. or 113 bd. ft., normal annual growth per acre.

the reduction factor on this forest was applied, in estimating, to each age separately, the growth per acre can be predicted separately as well, for these age classes giving the correct reduction per cent for each age class. But to simplify the illustration an average factor will be adopted.

the basis of area stocked: i.e., stocking reduced to normal acres, which weighs equally all age classes, the density factor averages 49 per cent. But on the basis of comparative present volume which gives greatest weight to the older age classes, the density factor is but $33\frac{1}{3}$ per cent. The latter ratio will be adopted for the first two age cycles for this reason. The empirical yield table then becomes,

TABLE 16. Yield Table for Bernice Division, Deerlodge National Forest.

Lodgepole Pine. Reduction to $33\frac{1}{3}$ per cent.

Age years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.
	180	60	1,620	90	3,160	120	4,540	150	5,640
	640	70	2,140	100	3,640	130	4,920	160	5,960
	1,120	80	2,680	110	4,100	140	5,280	170	6,240

The areas in the working circle are:

Age years	Area acres	Present yield M. bd. ft.	Age years	Area acres	Present yield M. bd. ft.
10	1,570	.....	70	1,928	4,125
20	9,742	.....	80	2,448	6,560
30	5,511	991	90	2,092	6,620
40	7,559	4,837	100	3,040	4,985
50	1,412	1,581	110	396	1,623
60	4,887	7,916			
70	1,928	4,125	Total		39,238 M
80	2,448	6,560			
120 to 160		14,443	Total	53,603 M	
160 to 200		2,844			
over 200		474			
Total Acres		58,346			92,841 M

the present volume in stands containing merchantable timber is 92,841 M bd. ft. of which 80 per cent is Lodgepole; therefore, growth can be based solely on Lodgepole without incurring too great an error. Of this, 53,603 M bd. ft. is in stands 120 years and over in age.

Calculation to Determine the Cutting Cycle. First Trial. The area now occupied by mature timber is 33 per cent of the total area stocked. On this basis, and to aid in establishing a cutting cycle approximately $\frac{1}{3}$ r, the cycle will be first tested at 40 years. The per cent of cut will be 66 or two-thirds of the present stand.

The minimum of exploitable age will be set at $r - \frac{1}{2}$ cc or 120 years.

The cut for the first 40-year cycle will be but 66 per cent of each stand leaving 34 per cent for the next cycle. This is approximated as the average per cent to leave. The older stands will be cut more heavily, and the younger, more lightly.

Growth in all stands is computed for $\frac{1}{2}$ cc or 20 years. On the older stands, above 120 years, an average of 37 board feet per year is calculated from the yield table and applied to all stands. This gives, on 17,761 acres, for 20 years, a total of 13,143 M board feet.

A more accurate method can be applied, which will be illustrated in the case of the stands below 120 years. Since the volume and age of each stand is known and therefore its relative density, the growth should be predicted directly on the existing stands.

This can be done by determining the per cent of increase shown by the yield table for a 20-year period for each age class, and applying this per cent to the present volume.

For 110-year class this is $\frac{4920}{4100}$ or 120 per cent.

For 100-year class it is $\frac{4540}{3640}$ or 124.7 per cent.

The yield of these stands in 20 years is then,

For 110-year class, 1,623 M plus 20 per cent or	1,947 M.
For 100-year class, 4,985 M plus 24.7 per cent or	6,216 M.
Total	8,163 M.

The total volume to be cut within the 40-year cycle is,

Volume of stands 120 years and older	53,603 M.
Growth at 37 bd. ft. per acre annually	13,143 M.
Volume and growth in 110 and 100-year stands	8,163 M.
Total	74,909 M.
66 per cent to be cut	49,439 M.
Annual cut, 1/40th	1,235 M.

At the beginning of the second cycle, the 34 per cent left from these stands already laid on an average of 20-years growth, and will lay on 20 years additional growth before cutting during this 40-year cycle. The growth of these thinned stands cannot be predicted with certainty, but such data as is available tend to show that this species has marked recuperation powers even to the age of 400 years. Hence it is assumed that on the remaining stand the growth will equal that laid on in the first cycle, or 37 bd. ft. per acre.

For 40 years and on 21,197 acres, this equals	31,371 M bd. ft.
Upon the residual stand of	25,470 M bd. ft.
or a total of	66,841 M bd. ft.

To this must be added the yield of stands now between 100 and 60 years of age, which will grow for 40 years in the first cycle and an average of 20 years during the second cycle before cutting.

Using the same method of percentages as for the first cycle, these are, for 60 years growth,

For 90-year stands $\frac{5640}{3160}$	or 178 per cent.
80-year stands $\frac{5280}{2680}$	or 197 per cent.
70-year stands $\frac{4920}{2140}$	or 230 per cent.
60-year stands $\frac{4540}{1620}$	or 280 per cent.

The yields of these classes will then be,

For 90-year stands at 150 years, 6,620 M, plus 78 per cent or	11,883 M.
For 80-year stands at 140 years, 6,560 M, plus 97 per cent or	12,923 M.
For 70-year stands at 130 years, 4,125 M, plus 130 per cent or	9,487 M.
For 60-year stands at 120 years, 7,916 M, plus 180 per cent or	22,164 M.

Total	56,457 M.
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per cent of these stands is cut as before, this gives a cut of
 with the older thinned stands gives a total cut of
 an annual cut of $1/40$, or

37,261 M.
 104,102 M.
 2,605 M.

by the plan of cutting but $\frac{2}{3}$ of each stand now, at a sacrifice of 637 M bd. ft. per year of the possible cut, it appears that the probable cut in the next cycle will be than doubled. If the stands are cut clean the respective cuts will be,

For the first cycle	74,909 M.
annual cut	1,872 M.
For the second cycle	56,457 M.
annual cut	1,411 M.
Total for both cycles	131,366 M.
Total, if $\frac{2}{3}$ is cut	153,541 M.

a reserve, in this case of 19,196 M or a total gain in production by the second of 41,371 M in 80 years or 517 M per year, which is about 32 per cent of the age 80-year cuts of 1,642 M by the first or clear cutting method. In effect, such a is equivalent to lengthening the rotation by at least 20 years.

ese figures are given to illustrate the method by which different cutting cycles and ions may be tested, to determine the actual yields and to decide upon the proper rs to use in regulation. They serve also to bring out the enormous influence of th upon the volume of the possible cut.

the discrepancy between the predicted cut for the first two cycles appears too t, the cut for the first cycle can be increased, and made more nearly equal with the ad, by shortening this cycle and removing the surplus of timber above the age of ears in a shorter period. It is suggested that the student perform one or more of e calculations by the methods indicated.

7. **Summary of Principles for American Regulation.** The European tment principle attains progress towards regulation by transferring stands ose age classifies them with a given fixed period, into an earlier or later od for cutting, thus equalizing the areas reproduced within the period advancing or retarding the normal age of exploitation for specific stands. The periods are of fixed length, equal to a definite proportion of the rotation, as the cutting cycle is usually $\frac{1}{2}$ to $\frac{1}{4}$ of this short period, there is no iculty in reaching and cutting any stand when needed.

n America the cutting cycle or length of time elapsing between successive s is determined by transportation costs and frequently becomes the govern- principle of cutting and hence of regulation.

The first principle of securing sustained yield in America is therefore to ermine the length of the first cutting cycle so as to fix the amount of the ual cut, on the basis of a *determined cut per acre*. As an aid in this deter- nation, the growth on cutover lands, in selection or group cuttings, and growth on cutover lands plus the young stands which mature, in even- ed forests, will be measured to indicate the annual cut possible in the ond cycle.

The annual cut in the two cycles can best be equalized by *lengthening or rtening the first cutting cycle*, the former reducing the cut in the first cycle d increasing it in the second, and vice versa.

Where more than two cycles are apportioned to a rotation, the per cent the rotation assigned to the remaining cycles may be made proportional the per cent of the area of the working circle, occupied by timber whose

age classes it with these cycles. The first two cycles can usually include all the timber *now merchantable*.

The working out of this principle is well illustrated by the above and as set forth it constitutes what has been termed the "American" method of regulation whose characteristics are, determination and equalization of the annual cut on basis of volume, *by means of varying the length of the first and second cutting cycles*, and determination of the actual annual cut by the principle of a felling reserve and cutting series with a minimum exploitation age of $r - \frac{1}{2}$ cc years and an allotment of areas or stands for cutting within the period, down to and including $r - cc$ years. Just to the extent that the per cent of the stand per acre, in many-aged forests, or the per cent of the total area of a logging unit, in even-aged stands, which must be cut is reduced because of increased accessibility and better transportation conditions, does the cutting cycle lose its controlling force in regulation, and the need for basing regulation on length of this cycle, and upon the cutting series and felling reserve which is created by it, diminishes, until with short cycles of 5 to 8 years and perfect transportation, the allotment principle of regulation may be applied without regard to the cutting cycle. But these conditions are for the future in many sections of the West, and the principles as described will be applied in cutting whether or not they are recognized; they should be in regulation.

178. Quiz. Can these principles be applied to even-aged stands? or to Even-aged mixed hardwoods?

How could the mixed hardwoods of the Southern Appalachians be regulated under present conditions?

Why must regulation be coördinated with silvicultural practice?

How can the annual cut in two cutting cycles be best equalized?

Why is this better than an allotment of areas for cutting within a definite period?

When should an allotment method be used?

APPENDIX

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APPENDIX A. (a) FOREST MANAGEMENT IN NINE EUROPEAN STATES.

The data on European management is a free and condensed and not a literal translation of the third edition of H. Martin's *Forsteinrichtung*. The wording has frequently been simplified but without changing the real meaning nor diminishing the value of the original text. The synonyms management plan, and working plan have been freely used. In some instances considerable liberty has been taken in completely rearranging the text. But in adhering to a translation at all, the "English" has had to be sacrificed to a considerable extent. The use of brackets to simplify some of the involved and complex German sentences perhaps has been carried to extremes but seems necessary to make the text understandable.

The following countries are included: (1) Prussia, (2) Bavaria, (3) Kingdom of Saxony, (4) Württemberg, (5) Baden, (6) Grand Duchy of Hesse, (7) Grand Duchy of Baden, (8) Alsace-Lorraine, (9) Austria. Martin's comment on French regulation has been omitted since this is discussed in great detail in the text and in the Appendix studies in French Forestry." Accepted principles proven by these discussions have been embodied in the main text of this book.

I. PRUSSIA. (Page 223)*

During the nineteenth century the allotment method was the dominant method of regulating the yield in Prussia. It came into use through G. L. Hartig, in the form of the strict volume allotment (*Massenfachwerk*). According to the Instructions of 1836 the yield was to be shown for all periods of the 120 year rotation (or period of regeneration), separated into main and preliminary yield, divided into classes (timber, fuelwood, round billets, brushwood). This method of Hartig's on account of the "unsubstantiated" of the calculations (for which a satisfactory basis was lacking), did not long be maintained. The elaboration of working plans progressed too slowly. Therefore new instructions were issued in the year 1836 by Oberlandforstmeister von

Figures in brackets denote the page in Martin's *Forsteinrichtung*, third edition, and facilitate reference to the original text.

Dr. Fernow, who kindly read the translation to Dr. Fernow, writes that Dr. Fernow . . . "thinks you have generally improved on Martin, whose style is certainly most robust" It should be noted that "abtheilung" means lot when "jagen" signifies compartment, but lot is usually the translation of "unterabtheilung" when the compartment is denoted by the German word "abtheilung."

An excellent way of mastering the variations and similarities of regulation in the foregoing states is to read through the translation subject by subject as well as country by country. For example take the subject of allotment by periods and it is instructive and that all states have usually abandoned the cumbrous and methodical scheme of fully allotting stands to periods 40, and 60 years hence.

Reuss, after summary yield determinations for the State forests had been carried the years 1826 to 1835; these instructions continued to be used almost to the end of the nineteenth century; to be sure, they are also based on volume-allotment but simplified the yield calculations and took area into consideration. At the same time attention was paid to a proper distribution of age classes and regulation of a series. In harmony with these instructions for the elaboration of working plans different kinds of allotment came into use according to the stand conditions in each case:

(a) The combined allotment (*Fachwerk*) which was preferably to be applied to irregular stands.

(b) The area allotment (*Flaechenfachwerk*) which under regular conditions was considered sufficient. Usually only simple areas formed the basis.

In recent times the yield calculations were limited more and more to the first period and the allotment for later periods was often entirely omitted. In other directions simplifications were also introduced. The most important essential prescriptions of the present use are as follows:

1. Prescriptions for the Elaboration of New Working Plans. (1) Preliminary discussion. Before beginning the work of regulation preliminary discussion takes place between the district forester, inspector and supervisor, in which (on the basis of detailed results of the former management), propositions for the future management are laid down. This discussion is centered on: the system of roads and division of the boundaries, maps and survey, the condition of the forest, the previous and present management, and the method to be followed in the organization of working plans.

2. Administrative Subdivision; (a) Working Groups and Management Classes. The formation of working groups is a special peculiarity of the Prussian State Forest management. Already in the instructions of Frederick the Great this is prescribed. To justify the formation of groups it is stated: "Partly the size of the forests and partly into one supervisorship and partly differences in portions of these forests as regards methods of management, condition of stands, market, or servitudes, make it desirable or necessary not only to regulate the cut for sustained yield for the Forest as a whole but to divide it into more or less independent organic parts of the whole forest forming main management units or groups, within which the sustained yield management may be either introduced immediately or at least prepared for by the establishment of ordered age classes." (P. 225) According to present practice each protection division forms a group. Such coppice forests that are to form a felling series by themselves as well as coppice under standards and selection forests, for which a special working plan is to be made, are segregated as special working groups.

Besides the division into groups, the formation of management classes is also prescribed in Prussia. The reasons for these are first of all to be found in the occurrence of the four groups of timber species on large areas (oak, beech and other hardwoods, softwoods, and conifers), and further in differences of management (especially regards rotation).

(b) *Permanent Subdivisions (Wirtschaftsfiguren)*. The prescriptions given for permanent subdivision essentially agree with the rules given in the first section of the first part (of this volume), which are derived from Prussian practice. This subdivision into permanent subdivisions (*Wirtschaftsfiguren*), which are here called compartments (*Jagen*), is made by a network of straight lines, which cut each other as nearly as possible at right angles. The rides (*Gestelle*) are to be laid out from east to west from south to north or parallel and perpendicular to an intersecting main road or railway. Where danger from wind is to be feared, the dividing lines are to be laid out so that they form an angle of 45 degrees towards the most dangerous wind direction.

In mountain forests the division is to be made on the basis of the network of roads. "The roads are to form the shortest possible connection to market or to means of communication with the market; they are to be planned in relation to each other and to cross mountains over passes and to be located so as to be easily built. The g

to exceed 6% except when thereby a specially favorable location of the roads is secured."

The shape of the management units is to be as regular as possible without acute angles, so far as possible facing in one direction and bounded or intersected by roads in a manner that all the wood cut in them can be readily moved to the highways. Boundaries are not formed by roads, either natural boundaries should be relied on or cultural limits, railroads or rides (Schneisen, which as far as possible are located in the direction of the steepest grade).

The size of the permanent management units is to average 50 to 75 acres—in spruce 62. The main rides of a compartment division, which run approximately from east to west, are marked with Roman (p. 226) capitals; the "fire-rides" which are perpendicular to these, are marked with small letters. The compartments in the plains are numbered from east to west, proceeding from south to north. In mountainous country, sections of country of uniform character are combined into groups and numbered accordingly.

Stand Divisions. The differences in the stands to be found within the permanent compartments are segregated as lots (Abtheilungen and Unterabtheilungen). Compartments are segregated, if the limits of the stand are likely to remain permanent and coincide with rides, roads, watercourses, etc. or can be laid out on lines suitable for roads, which are then marked with posts and direction ditches. In all other cases, especially when the difference is to be obliterated in the course of the first period, a segregation as lots suffices, the boundaries of which are not indicated and marked. Severance fellings and safety lines are to be segregated as lots. Compartments are denoted by small Latin letters, the lots by the compartment letters with a number (a^1 , a^2).

Site and Stand Survey. (a) **Description and Valuation of Sites.** For the general description of the soil and for its composition the geologic-agronomic maps of the Geological Survey on the scale of 1 to 25,000 are to be used. As regards termination, that of the German Forest Experiment Stations is to be followed. The site value is to be estimated on the basis of the Experiment Station yield tables. The average height of the main stand, ascertained by a few measurements, serves as measure of site value.

(b) **Description of Stand.** This is to be brief. Uniform stands of regular character are sufficiently described by stating the species, age, and the full yield. Striking features of the stand are to be specially noted. In uneven-aged stands in which the age classes gradually merge into each other, the age limits and the average age are to be noted. If several age classes are strictly differentiated, the age of the classes is to be noted (p. 227). The degree of density is to be estimated specially for the different species. Their sum must coincide with the total density of the entire stand.

(c) **Age Class Table.** This table forms the most important numerical basis of the management plan in the timber forest; in it the stands are arranged according to sequence of age groups, compartments and lots. In mixed stands, and in those containing several age classes, the areas are divided according to the proportion of these differences. The area (to be determined by survey or estimate), which each species and separately stated age class occupies (within a compartment or lot) is entered on a separate line. Thus it is possible where mixed stands predominate to record the yields more correctly than can be done, if, in the table the whole area is assigned to the dominant species. The areas are compiled, separately according to the four species groups and, if several management classes are involved, also separately for these, by compartments and in totals.

If it appears desirable to record and compile the stands according to site class levels, this may be done. On the basis of such data it is possible to calculate or estimate the actual and normal growing stock of the age classes and of the total forest.

Regulating the Cut. (a) **Standard of Measure.** The measure for the amount of cut and the proof of sustained yield is the normal periodic area. This is determined for each management class according to the relation of the length of the period ($= 20$

years) to the rotation. For the working groups it is not necessary to adhere to a normal felling area. With irregular age classes corresponding changes are made. The area of the first period is to be made smaller when there is a deficiency,—larger when a surplus of mature timber exists. Under difficult (cultural) conditions and especially when species with long regeneration periods are involved, the first and second periods are to have felling areas allotted. In cases where the sequence of cuts has special significance the progress of fellings is to be shown for a longer period. The felling areas of the first period are listed separately according to species, groups and management classes, group by group and for the whole forest. For the areas of latter periods and the segregation of stands according to species, groups and management classes are not required.

(b) *Choice of the Stands to be Regenerated* (p. 228). The correct choice of the stands of the present period of management is considered one of the most important tasks of forest organization. It is essential that the stands are utilized at time of maturity, that the most suitable felling series is established, the sustained yield assured, and the most suitable species regenerated.

(c) *Rotation*. The (official) determination of the rotation for the main species is reserved for the Minister. The proposals for the length of the rotation are to be prepared and argued in the preliminary proceedings. For a decision on the length of rotation the data are to be secured in suitable "reviers" (before the organization takes place) for the most important species and the most commonly occurring sites; the stump prices (free of logging cost) per cubic meter of timber for the most important species and classes can thus be studied.

6. **Determination of Timber Volumes and Cut.** (a) **Main cut.** The allotment of the cut (main and intermediate) is done according to the instructions for keeping a control book. The yield (main cut) is composed of the present volume plus the increment for the next ten years. All volume data refer to timber and are separately determined according to the four species groups already mentioned.

The determination of the volume of the first period is made by caliperings all stands unless a simpler method appears satisfactory. For the calculation of the volume the volume tables of the German Forest Experiment Stations are as a rule to be used. The volume of the young regular stands is estimated by yield tables or ascertained from sample plots. The increment percents are cited according to the yield tables; for stands simple increment investigations are to be undertaken. The annual felling budget is then obtained by dividing the sum of the volumes assigned to the first period by the number of years in period (i.e. years in period).

(b) *Intermediate Cuts* (p. 229). To furnish a definite basis for the execution of thinnings, a plan is elaborated in which the areas of the stands to be thinned or cleared in the next decade—separated into those under and over 40 years—are enumerated. The division of these areas by ten gives the yearly thinning area. If the stands are to be thinned twice (or thrice) in one decade their area is added again (or three times). The exact year of the thinning is not dictated for each stand.

The felling budget for the intermediate cut is estimated on the basis of the yields of the intermediate cuts . . . have furnished on the average in recent years, excluding unusually high or low yields. The average is increased or decreased if the annual yield is to be thinned deviates considerably from the area annually thinned (in the years of comparison) or if other reasons give occasion for it (especially changes in the thinning technique).

7. **Coppice and Selection Forest Organization.** (a) **Coppice.** Extensive coppice forests are segregated as special working groups. Every group is to contain a number of annual felling areas corresponding to the rotation and with approximately equal areas. The felling areas are chosen according to their maturity and with regard to a satisfactory felling series. It is generally considered sufficient to determine in each group the number of felling areas and the year of their cutting, without locating individual areas in the field or on the map. Lots are not segregated.

The yields of timber and brush are to be estimated on the basis of former res-

annual cut is found by dividing the number of years of the rotation into the sum yield of all felling areas segregated by the species groups.

Selection Forest. The regulation of the cut is simple. A segregation of lots of the compartments is as a rule to be avoided. In the age class table the areas of species and age classes are to be estimated and stated separately. The ascertainment of the growing stock stem by stem is not necessary. All wood yield is to be regarded as main cut.

(p. 230) The cuts for each management unit of the first period are estimated from tables according to the maturity (of the parts) of the stand *for the middle of the period*, segregating (as usual) the four species groups; or are estimated by calipering. In a selection forest forms a special group the average increment for every management unit is estimated and the total increment revealed thereby is to be considered as the prescribed cut (felling budget), in so far as the age group proportion does not reveal a shortage or excess of growing stock, or the character of the stands does not necessitate a reduction or reduced cut.

Whenever the selection forest has been in existence for a considerable time the future prescribed cut may be deduced from a consideration of the changes in the age group proportions consequent upon the application of the previous felling budget. For a check on the progress of fellings a return period of ten years is as a rule established.

Control and Development of Working Plans. A. **Control.** For control of the management and for the development of the working plan there is: (1) the Control Book, (2) the Ledger, and (3) the Area Register.

The **Control Book** serves as a check on the estimates and fellings, and consists of three parts.

The *first part* (A) contains for every permanent stand a special record in which are entered annually, all fellings divided into main and intermediate, with the amount of material realized. The main cut includes those cuts of the main stand which either effect an entire renewal of the stand or such a culling as to necessitate its entire renewal or filling in, or if there is a considerable diminution of the main yield as determined by the stock taking. The intermediate cut includes: (a) thinnings in the under-story; (b) fellings of single stems and groups carried out for the benefit of the main stand, which do not necessitate a renewal of the stand and (p. 231) which do not exceed 5% of the prescribed main yield (cleanings, improvement cuttings); (c) fellings which take place in consequence of injuries to the forest without, however, necessitating replanting, and without diminishing the prescribed main felling by more than 5%. Cuts from (a) to (c) which take place in stands of the current working period, are considered as main fellings.

The yields of the coppice under standards and selection forest are also reckoned as main fellings. When the cut prescribed by the working plan (in the main felling of a timber forest) is completed, the realized yields of timber are summed up and transferred to the *second part* (A₁) (see page 180) and here compared with the estimated yields. The intermediate yields are excluded from this transfer as is also the root yield of brush-wood. Every three years the part A₁ is balanced; it is then calculated whether the stand divisions (re final cut) during these three years have yielded more or less than the estimated yield and what amount of wood above the estimate may be added or how much the felling budget must be reduced (to make up for a deficit). The *third part* (C₁) contains the annual comparison of the cut in timber with the estimated amount, taking into consideration the changes demanded by the results of the first part (A₁). Excess or deficit in one year's fellings (as compared with the felling budget) is entered for the determination of the usable volume of fellings added or subtracted from the felling budget. The result (the remainder or the sum) constitutes the standard for the following economic year; the permissible cut (in the main felling) may only be reduced by 10% at the highest, without Ministerial permission. No limitation exists in this direction for intermediate returns; they are controlled only by area (and by cultural practice).

The **Ledger** (*Hauptmerkbuch*). This aims (in conjunction with the Control

Book and the Area Register) at furnishing the bases for the control, providing (p. 232) correction of the forest management. "It is to form a history of the Revier which enables one to see the development and changes of conditions in the Revier as well as in its integral parts, and furnishes to the succeeding administration a knowledge of events influencing the management, the measures adopted, the work performed, the observations and experiences had, at the same time permitting at any time the oversight of the status of the management, and hence also furnishing a needful basis for new organization work." In conformity with these purposes the Ledger is divided into a general and a special part.

The *general part*, arranged according to subjects, contains in historical sequence the noteworthy changes, phenomena and occurrences which concern the whole Revier. Large parts of it are of a general nature; it takes up the noteworthy data recorded in the course of management as well as any suggestions regarding improvement.

The *special part* of the Ledger is intended to record the events and changes occurring in the individual compartments; especially the changes in the stand produced by felling and forestation; the logging costs are specified and explained. Certain parts of a special map on a scale of 1:5,000, made for the use of the supervisor, form an addition to the Ledger and to the Area Register; on these are entered the changes in boundaries, the methods of using the soil and the stand changes made by felling and forestation. If a road system has been planned, a road system map is put into the Ledger on the scale of 1:25,000, and also a blank map (on the same scale) on which the finished roads are entered. Detailed instructions for the correction of the map are given in the manual.

3. The Area Register. The status of the area of the reviers is controlled entirely by the Area Register, which consists of four parts: Section A, the map register, records all existing maps, surveys and working plan data; Section B records all changes which have been begun; in Section C the entire area of the Revier is controlled and Section D records the transfer of soil intended for wood production to areas not intended for wood production and vice versa.

B. Intermediate Revision (p. 233). The working plan is revised at the close of the first period (usually 20 years), but, in view of disturbances and changes in management occurring during the course of the period, an intermediate examination is undertaken in the eleventh year. To prepare for this the supervisor has to balance up the most important control books having reference to felling and forestation. At the plenary conference, then taking place, a discussion ensues whether and in what respect there has been deviation from the regulations of the working plan or whether there is to be such deviation in the future. The working plan is then checked and revised as follows: (1) All changes in the felling time of stands of the first period; (2) the felling budget for the main yield according to the urgency of the necessary changes; (3) the felling budget of the intermediate yield; (4) the thinning plan for the next decade; and (5) if necessary, the road building plan.

II. BAVARIA.

The most important basis for forest organization has been up to this time the Instructions of 1830 together with some supplementary directions. Essential prescriptions are also contained in the basic protocols and the revisional notes of the ministry of agriculture and individual working plans. New directions for working plans are soon to be expected. The most important points which characterize the past procedure are the following:

(1) **Preliminary Work and Bases (p. 234)** (a) **Subdivision.** Large forests are segregated into districts, i.e. separate forest regions formed by natural conditions, and of contiguous location; they generally are named.

The permanent units of management (formed by systematic division), and which are marked by Arabic numbers, are called compartments. They are formed in the mountains by straight rides (Schneisen). In the mountains the division lines are adapted to the contours and connected up with the road system. Moreover the compartments are determined on forest conditions and management. Their size and shape are often very dissimilar.

es in the existing division are avoided as much as possible. No positive directions are given for the size of compartments. Varying parts of the compartments are treated as lots (marked with a, b, etc.). As regards their size no general prescriptions are given, but as a rule they are not to be less than $2\frac{1}{2}$ acres. Differences in the lots (wind fall openings, regeneration groups, etc.) are recognized by special exponents ($a^1, a^2, \dots$). Regarding the character and the direction of the cuts, general prescriptions are given in the management plan (which are elaborated for working units) and special prescriptions for periodic fellings.

Basic Protocol (p. 235). Before beginning the survey the main features of the management are to be determined. This is done in a council of commissioners. It has reference to all conditions which are of essential influence on the wood production (soil, situation, increment, yield, market, legal conditions, etc.). Moreover the former management (in its most important technical and economic aspects) is described. The future management plan in its main features is determined from the present plan. At the same time there is given here the basis for the segregation of working groups occasioned by difference of species and of rotation. The results of the council meeting are recorded in a "basic protocol."

Description and Determination of Cut. The permanent bases for determining the management (especially the site conditions) are stated for entire compartments, so far as no essential differences occur in their component parts. The conditions which are of a primary nature, especially the stand conditions and measures of management, are stated for the lots. The description of the stand is to emphasize in the briefest possible manner the conditions which are of moment to the management, especially the dominant species, the mixtures, growth, density, and age. The age classes were hitherto determined that each class comprised a period of a quarter of the rotation. In the future, the age classes will be established with 20-year periods (I. Class, 1-20 years, II. 21-40 years, etc.). The determination of the growing stock is by complete calipering for the stands which are to be exploited during the next period, unless simpler methods are indicated by former surveys or by experience of past management. The growing stock of later periods, as far as it is to be determined at all, is to be estimated from yield tables on the basis of average increment.

Working Plan. (a) **Method of Regulating the Yield.** The former method of regulation was a combined (area and volume) allotment (p. 236) method (Fachplan) with 24-year periods. In recent times the yield regulation is confined to the next period, which in future will comprise only 20 years. The allotment of the areas is made by working groups, beginning with those under the longest rotation. Within the limits of the stands are enumerated according to the order of numbers of the districts, compartments, and lots. The working plan is to furnish a control over the management as planned. The prescriptions are, however, so formulated that the management is rigidly fixed for long periods. The allotment of the stands to the periods of the working plan is based largely on average age. Deviations from this rule are indicated by the condition of the stands and considerations of the establishment of a good felling (which is helped by suitable severance fellings).

(b) *Determination of the Felling Budget.* The yield of the stands (lots) is calculated by adding to the present volume the increment for half the period. The felling budget for the main cut is determined by multiplying the felling area corresponding to the rotation ($\frac{a}{r}$, if rotations vary for separated working groups) with the average wood

volume of the area unit of the stands to be felled. To this are added the volumes of expected fellings and accidental yields. In case of irregular age class conditions suitable increases or decreases of the felling areas are made. The budget is stated in toto, separated by species.

The yields (special estimates by yield tables) of intermediate fellings are given only for the first half of the first period. The total volume of thinnings is also stated in

per cent of the total yield and per acre of forest area. The annual budget intermediate yield is from estimated total volume divided by the number of years.

(c) *Special Management Plan.* To give the management needful suppleness rule to allot in the working plan more areas than correspond to the debit of utilization. Stands are allotted to the working plan (which in future is to be made for 10 years), which contain 15 to 30 times the yearly budget (p. 237). This affords the flexibility of multiplying felling areas and making gradual progress with regenerative fellings. The "basic protocols" give directions to the supervisors for the local fellings.

Besides the felling plan there is a special forestation plan, which contains a forestation cost estimates arranged by lots. Plans are also prepared for the construction and maintenance of roads (and eventually for the most important secondary roads).

3. **Control and Revision.** The control of the fellings and stock estimates are carried on as in Prussia:

(a) By annual comparison of the total cut with the budget. The tabulation shows the main cut, intermediate cut, and total cut.

(b) By periodic comparison of the felling results with the estimates for each year which is carried in a special record. At the end of the 10-year working period the Control Book is balanced.

The periodic examination and revision of working plans, which may be either partial or comprehensive, is done by the Forest Revisions Bureau (Waldstandsrevisionsbureau). The plans are "comprehensive," if important changes become necessary through extraordinary natural phenomena or for other reasons. Essentially, the revisions are carried on as in Prussia.

III. KINGDOM OF SAXONY.

The forest organization for a long time has been carried on by a separate bureau (Forsteinrichtungsanstalt), which has had special advantages for its development. Through this special bureau, the personnel is well trained and a uniform execution (p. 238) all survey work is secured. The results of the working plans can be effectively worked over and their relation to other technical branches (experience, administration, economics, statistics) more appropriately kept in view. In Saxony the yield regulation is based on the allotment method (Fachwerkmethode). H. v. Spreti, who systematically carried on the survey and organization of the Saxon State Forests in the years 1811-1831, advocated the area allotment as well as the combined allotment. Due to the regularly recurring revisions, it was early recognized that the yield calculations for later periods were superfluous. The allotment for these was therefore abandoned and the yield regulated only for the next decade. The most important points characteristic of the Saxon procedure have reference to (1) the preliminary work of estimating, (2) the determination of the felling budget and felling areas, and (3) the control and revision.

1. **The Preliminary Work.** The subdivision into permanent management units (management compartments) is (in the plains and in gently sloping country) done by a system of straight lines intersecting as far as possible at right angles. The main lines, so-called Wirtschaftsstreifen (management lines or strips) run in most reviers of Saxony from northeast to southwest. They serve as boundaries of the felling series and are 9 yards wide in order that along their limits breaks (i.e., severance fellings) may be formed for protection against wind damage. The rides, which are located at right angles to the management strips are to indicate the direction of the annual felling areas and are 4.5 yards wide.

In mountain reviers too, in the middle of the last century, the subdivision was carried out on similar principles, except that the division lines conform to the more important contour lines (ridges and saddles). With the progress in making roads (which are laid out about independently of the subdivisions), many lines were replaced by roads. A sudden and systematic change of the existing subdivisions (as was carried on in the Prussian mountain districts) could not be carried out because of the prevalence of spruce

to windfall, and because of the straight division lines along which severance is made. In working out road systems (in each case), it is investigated whether and how far the roads are to be used as division lines and what changes (if any) are to be made in consequence of the new road system.

(p. 239) lots (stands) mainly due to differences of age, are segregated down to a minimum area of $\frac{1}{2}$ acre. Binding rules are not given, however, in this regard. The marking of the limits of lots is not attempted unless existing lines can serve. In account of the uniformity of stand conditions the descriptions of lots are made in a tabulated form. The soil classification is made by site and stand qualities. The former gives expression to the normal, the latter to the actual conditions of production. The segregation of sites is made according to the Instructions for Forest Experiment Stations. The stand quality is expressed in simple numbers, which show the combined effect of site and condition of stand. The age classes are stated in 20-year gradations (I. class 1-20 years, II. class 21-40 years, etc.). Each age class is again divided into decades. The resulting classification in decades is also shown on the maps.

To ascertain the growing stock, the volumes of the stands below 40 years are calculated on the basis of yield tables (based on stand quality and age classes). The stock of stands above 40 years is ascertained by ocular estimate, which is done at each ten-year main thinning. Calipering is the exception. With regular stand conditions, the predominance of clear cutting, uniform stand management, the exact statistics of the results of forest management plans, and the ability of the permanent personnel, the ocular estimate has hitherto given good results.

The Determination of the Annual Felling Budget. Rotation. (a) **Measure of Rotation.** If a clear cutting system is employed, the normal annual felling area furnishes an easily applicable measure of the annual cut. The determination of the rotation depends chiefly on expert judgment (based on existing rotations, on the requirements of the market, and on the price (p. 240) relations of the timber size classes). To determine the normal rotations investigations were formerly made for spruce (which occurs throughout the whole country) and index per cents were calculated for characteristic stands. For the calculation of the volume increments per hectare ample material is on hand. The calculation of the value increment per cent is based on the auction prices of the various timber size classes, which compose the average cubic meter of the stands of the various age classes. The value relations of log sizes (which are classified according to a middle diameter of 6, 6-8, 8-11, 11-14, 14 inches) indicate the value increment per cent.

With regular stand conditions the normal felling area is observed as accurately as possible, which offers no difficulties in the prevailing clear cutting system. Under irregular conditions deviations become necessary. The age class condition serves as an indication of the degree to which these appear desirable or allowable. If the older age classes are in excess, more area is included in the felling budget, and vice versa. It is therefore laid on an accurate estimate of the age classes.

(b) **Determination of Felling Areas.** For felling during the next period of management, stands are chosen, which, according to age, soil, and stand conditions are mature and in order of the need for felling. Next in importance in the choice of the felling areas is the regulation of the felling series. Since the spruce predominates, this consideration is of great importance for the whole country. Regarding the danger of windfall stands that the fellings proceed in a direction opposite to the dominant wind. If the annual clear cuttings remain narrow and only gradually merge, the general result is that the felling series remain short.

In order to satisfy the demands of these felling rules and to counteract the dangers which the segregation (or grouping) of large, even-aged stands may provoke, it is necessary that one have command of a sufficient number of points of attack. To secure this, the boundaries of the stands must early be accustomed to an open position through the formation of low crowns, especially where those stands are located so as to be exposed to storm by the removal of old stands in front of them. This is accom-

plished by making the *management strips* sufficiently wide, by *severance fellings*, and cutting around those stands that can still develop a wind firm belt.

(P. 241) The most important task of forest organization lies in properly laying out the order of the felling areas. The contiguous felling areas assigned to the management period should not be larger than the rules of the progress of felling can justify. The future formation of the felling series (their continuation, interruption, etc.) is dependent on conditions which (at the time of the making of the working plan) can not yet be foreseen.

(c) *The Justification of the Felling Budget.* The felling budget is listed separately for main cut, clearings, and intermediate cuttings (thinnings, cleanings and accidental fells). After the felling area has been decided upon, the main felling budget is based on an ocular estimate of the growing stock (on the felling area). Estimating the growing stock is proven sufficiently accurate for purposes of fixing the budget. To control the growth, the estimated volume, the amounts per acre (of felling area) are compared with the results of the last decade's fellings; important deviations from the average hitherto obtained must be justified. The actual annual increment (which is calculated according to the age and age classes with the aid of the yield tables) also indicates the felling budget; compare the increment thus obtained with the yield possibility of the *revier*, the *revier* increment is also calculated by site classes.

The probable yields from thinnings are estimated on the basis of the results of the last decade (with the aid of yield tables) taking into special consideration the conditions of the stands. The separation of broadleaves and conifers is made only if broadleaves form a substantial amount (of the stand).

3. *Statistics.* The data collected by the working plans bureau (for every *revier* for the whole country) date back to 1817, or in part to 1844. The importance of permanent records for working plans (p. 242) can best be shown by the Saxon yield statistics; therefore their results may find place here. The most important data are:

1. **The Age Classes.** In the State Forest the present condition of the age classes is as follows:

Class	I	II	III	IV	V	VI		
						Open and bare	::	Total
Per cent	23	21	25	18	11	2	::	100

2. **The Sites.** According to the last accounts the qualities are:

	I	II	III	IV	V		Average quality
Site qualities %:	3	36	49	11	1	::	2.7
Stand qualities %:	1	16	53	25	2	::	3.13

3. **Growing Stock.** This has in the second half of the 19th century increased from 152 cubic meters to 187 c. m. per hectare of forest area (from 2173 to 2674 cu. ft.) in the last 30 years it has remained pretty much unchanged.

4. **Main Stand Increment.** The normal increment corresponding to the site qualities is estimated for 1 ha. at 6.18 c.m.; the actual increment (corresponding to the actual site qualities) at 4.84 c.m. (88 and 69 cu. ft. per acre). The annual felling budget of the last revision period amounted on an average to 4.21 c.m. (60 cu. ft.).

5. **The Fellings on 1 Hectare of Forest Soil** amount on the average to:

	1854-63	1864-73	1874-83	1884-93	1894-03	1894-08	
Timber	3.44	4.28	4.72	4.88	5.03	5.34	c. m. per hect.
Total volume	5.01	5.85	6.48	6.43	6.39	6.23	" "

6. **The Proportion of the Timber Size Classes.** The timber per cent has in the course of the past century risen from 17% (in the decade 1817 to 1826) to 82% (in 1908).

The Income and Expenditure and the Net Yield in marks per ha. of the entire mounts on the average to:

	1827-36	1837-46	1847-53	1854-63	1854-73	1874-83	1884-93	1894-03	1904-08
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Income:

	18.6	20.2	25.6	35.4	49.1	62.4	66.7	76	90.4 M
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Expenditure:

	8.6	9.1	10.2	11.5	13.9	20.8	23.0	28.9	33.2 M
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Net yield:

	10.0	11.1	15.4	23.9	35.2	41.6	43.7	47.1	57.2 M
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The Forest Capital was estimated (in marks per ha. of forest soil) to be:

1854-63	1864-73	1874-83	1884-93	1894-03	1894-08
1156	1417	1682	1859	2206	2311 M

243) To calculate the forest capital, soil and stand values must be ascertained. Soil value is estimated for the average area of the different reviers on the basis of station values. The value of the growing stock (for stands up to 40 years) is related by cost value formulae. The interest rate is based on the relation of the yield to the forest capital.

Control and Revision. The felling budget (classed as final and preliminary cuts) summed up as a total budget (the amount of timber to be cut and controlled is fixed). At the end of the 10-year management period, a *main revision* takes place; and in the middle of the period an *interim revision*. In the *main revision* an entire redrafting of the felling plan takes place (on the basis of a new valuation of the revier). In the *interim revision*, necessary additions and corrections are considered; especially; (a) forestation, (b) comparison of the felling results with the estimate, (c) deviations of the fellings from the plan and (d) miscellaneous. Moreover the nature of the revision is dependent on the changes in the forest management which have taken place (as compared with the working plan), while the details of the revisions are determined by the instructions for the formulation of new plans.

Maps. For the management plan the Saxon stand maps are of the greatest importance; these show (on the scale of 1:20,000 or 1:15,000) the species, the age and the felling series. The felling areas of the next decade, the sequence of fellings, the distance between fellings and the liberation cuttings are specially marked on the maps.

IV. WÜRTEMBERG.

The Instructions (printed in 1878) for the elaboration and renewal of working plans are based on the combined allotment method as a basis. In the year 1898 these Instructions were changed and supplemented by new regulations which abrogated the area allotment plan and limited the regulation of the yield to the allotment (p. 244) of the felling area for the first period. These regulations are in force for State and institution forests. The most important regulations concern the preparatory work, the formulation of the working plans and their execution and revision.

Preparatory Work. The regulations regarding the formation of working groups and the subdivision for management are of the next greatest importance (i.e., after the prescriptions for the determination of the felling areas, the surveying and mapping).

The Forming of Working Groups. Different methods of management and diverg-

ence from the normal rotation are emphasized as reasons for their segregation: each working group an independent age class relation (with special order of felling) is to be attempted and a special felling series established.

2. **Subdivision.** (a) **Districts.** As a rule the different large forest areas: administrative unit are segregated as districts. Their main purpose is to afford simpler orientation.

(b) **Compartments** are considered as the *permanent* local cornerstone of management. It is intended in the course of time to eradicate the differences occurring within the compartments (and lots) which on account of their form and size do not seem convenient. The average size of the compartments in moderately large working groups, for leafed trees and conifers, must not exceed 35 to 50 acres. Their boundaries should be located as far as possible on natural contour lines and on roads to facilitate identification, to economize area, to protect the edges of stands and to enable careful skidding of logs. "The main road system generally forms the basis of subdivision."

(c) **Lots** are the unit for the felling and silvical measures of the working plans: reasons for the segregation of lots (not to be too rigidly carried out) are:

(P. 245) I. When the stand and soil on a part of the compartment is so different from the rest that a similar management (especially simultaneous regeneration) could not be taken place;

2. When some species occurs other than that dominating the compartment;

3. When the dominant species shows a variation in age of over 20 years.

The boundaries of the lots are generally not marked in the forest. The lots are shown on the map by small Latin letters, which also indicate the age classes (a = 21-40, c = 41-60 years, etc.).

(d) **Felling Area Division.** In coppice and coppice under standards only the division into yearly or periodic fellings is necessary.

II. **The Working Plan.** The general order reads: "The entire management is to be so regulated by the working plan that its purpose may be attained as quickly and completely as possible—the most advantageous use of the forest,—at the same time securing a sustained yield, and with due consideration of the objects and needs of the owner."

1. **Form of Presentation.** The most usual form of the working plan (from its long existence) is:

District and Compartment.	Sub-Compartment																		
	comp.																		
	Yield Area.	Letter.	Area.	Site-Class.	Stand Description.		Age-Classes					Method of Management.	Thinnings	Cleanings	Cultures		Main Yields of 1 Per		
	ha.	ha			Age.	Species and Stand Form, Relation of Mixture.	1-100 81-100 61-80 41-60 21-40 1-20 clear.								Seeding	Planting	Area-Basis		Yield (timbe
					Degree of Cover.														1. Decade

method, at present only the area for the first 20-year period is actually allotted. Standard for the utilization area to be segregated, is the normal area of the 20-year; but where there is a deficiency of mature stands, this is reduced, and if an above the normal amount, it is increased. The recording of the areas is by lots. It is only partly assigned to regeneration in the first (I) period, only a corresponding part of its area is to be allotted to the (I) period (except for special cases); the remainder is left out of consideration (i.e. in group regeneration cuttings, seed fellings). In choosing the stands to be regenerated, the following must be weighed: a regeneration of these stands themselves, a good felling series, and an arrangement of the area with a corresponding local distribution of age classes. A development of the area (injurious to the technically correct cutting) must be prevented by sufficiently liberalization and improvement fellings. In large conifer areas, a gradual formation of the area and, so far as possible, independent felling series must be particularly striven for. Accurate stand maps (colored if possible) are to be used for planning the work which measures are also to be noted). For the purpose of enlarging the basis of the area plan, it appears desirable to consider the second (II) period as well as the first (I), its area must be also segregated.

Plan for the Main Cut. Up to the year 1898 the regulation of the main cut was in accordance with the simplified combined allotment method (described in the literature by Hebe, Graner, and Stoetzer). At present the regulation of the yield is limited to the first (I) period. The total of the lot yields assigned to the (I) period forms the basis for the periodic budget. These yields are determined according to the condition of the stand, and after a consideration of the felling series and the age class relations. Additional fellings are to be added to the cut (from the stands not included in the area plan of the (I) period); . . . these are estimated according to average conditions without trying to consider (p. 248) the amount produced by unusual natural phenomena. The main felling budget of the next decade is, as a rule, to be put at half the yield of the first period. All yield data refer to timber. The volumes for the (I) period are usually secured by calipering 100% of the stand.

Area Plan of Thinnings. For carrying out the secondary fellings of the first decade either a mere area plan is provided, or else in addition an estimate of the timber volume (in cubic meters). All secondary fellings are to be treated as thinnings without reference to the age of the stand.

Other Matters in Working Plans. Besides the plans named there must be added to the working plan: an area plan for cleanings; an area plan for the forestation to be carried out in the first decade; and a plan for the use of litter.

Statistics. Since the year 1882 annual reports are made, which give the results of the management of the past year. These also include periodically the results of the working plans.

I. Execution and Revision of Working Plans. I. Control. "In carrying out the area fellings in the timber forest," says the forest service manual, "as well as in the standards (coppice under standards forest) a volume control is applied so far as a limit of volume has been set. For the secondary fellings (in the timber forest and in the coppice under standards) an area control is to be used so far as the working plan provided for thinnings." The unit controlled includes the cubic of timberwood (Kubholz, 3 inch diameter and over).

II. Renewal of Working Plans. (a) Main Revision, (p. 249). This takes place at the termination of a decade. Either an exhaustive revision of the working plan in its essential parts is made, or merely a correction of the existing plan (especially as regards the fellings and forestation) depending on the changes which have or are to take place during the decade, through natural occurrences or economic conditions.

(b) Interim Revisions. In timber forests of more than 750 acres an interim revision is made at the end of five years; this considers mainly the felling budget and the influence of any natural injuries on the utilization.

V. BADEN.

In Baden also the yield regulation has been first of all by the allotment method (volume allotment). This method, however, did not appear suitable under the present forest conditions which are characterized by natural regeneration (especially of fir). Since the regeneration of the fir (including the preparatory cuttings) requires much longer than the 20-year periods, the management could not be adapted (as a basic condition of a good method) to the framework of the yield regulation.

For about 60 years decennial revisions have been made in Baden working plans. The results (the budgets actually realized and their effect on the condition of the forest) form an important basis for practical management. The present method was introduced in the year 1869. Essential changes in the present rules are expected in the near future as evidenced by the literature. The most important points of the new Baden method are:

1. **Preparatory Work (p. 250).** Before drawing up a working plan there is an investigation of the forest by the officials charged with the work and the last plan is fully investigated in all its details. This investigation includes the subdivisions of the forest, the former site and stand descriptions, the estimate of the growing stock, the increment, the results of the previous working plan and the principles underlying future management.

The general descriptions refer to the data on the site conditions, the existing species, method of management, rotation, management rules, etc. For each compartment there is a brief description of the area, the stand, the growing stock and the increment. The growing stock in the compartments under regeneration is calipered; elsewhere a rule it is estimated by yield tables, past experience and by sample plots. For a long time special weight has been laid on the estimate of the current increment for regulatory purposes because of the present stand conditions (there was otherwise no sufficient basis). The importance of increment for the regulation of yield is emphasized in the most recent instructions. In the report, yield tables and sample plot data are given, but in the elaboration of the working plan special local investigations are also made (in suitable stands). Besides the current increment (which is the objective of the investigations) the mean increment at the felling age (accepted rotation) is also established.

2. **Determination of the Felling Budget.** The determination of the felling budget is derived by Karl Heyer's method (i.e. felling budget = total increment in period of regulation plus difference of actual and normal stock divided by period of regulation). The actual increment is thus the main basis and measure of the felling budget. The current increment was conceived and determined according to the Instructions of 1869: "The current increment, 'as it will probably take place in the next decade.'" In consideration of the difficulty of an accurate calculation and the limitation of the use of the results of the calculation on the main felling budget, it appeared advisable to let the current increment at felling age take the place of the current increment (p. 251).

The growing stock is estimated for all age classes according to the actual volume of the stand. In each age class the normal stock corresponding to it (to be ascertained by the use of yield tables) is employed for comparison with the actual growing stock. The total normal growing stock is besides to be determined according to the formula: increment on total area for half the rotation. "More than the increment is to be used if an excess above the normal stock exists, the utilization of which appears silviculturally and economically advisable. Less than the increment is to be used when the normal stock is not yet in existence. In the latter case the quicker the normal stock can be attained (by saving of increment) the better, provided that in doing so no essential economic loss or mistake in management is caused; in no case, however, the equalization period be longer than the rotation. With these principles in mind the felling budget is determined for each given case according to forest conditions and the special needs of the owner; but it must not be forgotten how undesirable it is

r communities and corporations, to have any considerable variation in the felling t in the various decades, and how greatly this variation would detract from the ing of forestry. A steady gradual rise in the felling budget will be considered more desirable by every forest owner, rather than a rapid rise, which must be ved by a considerable fall later on; the reverse is also true. Moreover, it is to pected that in almost every decade, extraordinary happenings and needs make ordinary utilization necessary, and that therefore very often the established budget be exceeded. In case of doubt therefore, it is good policy to be conservative. To ain budget (figured as above) the secondary fellings are to be added according imate. Overcuts and undercuts, which (according to the rules of management o be compensated for in the new decade) must, in so far as they affect the main be considered when the new budget is decided upon. The budget for the coppice oppice under standards forests, which are regulated by area, is the actual yield e annual felling area (and is thus determined by area and not by volume).

Statistics (p. 252) are closely connected with forest organization. A uniform od of statement was established in Baden in 1869 to simplify the general descrip- in working plans, and to obtain good data on forest history and yields. The nistration officials begin the statistics, which are continued and completed by the ators when the working plans are revised. The importance of good connected stics for forest organization is clearly recognized in Baden. The most important stical data are:

The Rotation. In the State forests 59.4% of the area is under 120 years rotations, 100 years, 9.4% 90 years, and 3.4% 80 years.

The Increment. The actual volume increment at felling (rotation) age is placed 9 cubic meters; the normal is 5.4 in the State forests.

The Growing Stock. This is shown since 1862, when it amounted to 220 cu. m. the timber forests, a steady increase up to the present figure of 290 cu. m.; the al growing stock is estimated at 299 cu. m.

The Felling Budget. This amounts (according to present conditions) in main ngs to 4.5 cu. m., in secondary fellings to 1.6 cu. m. The cut has increased from cu. m. in the year 1867 to 6.31 cu. m. in the year 1907.

Average Prices (for log classes according to the Heilbronner standard). The age price per cu. m. has risen from 8.63 marks in the year 1867 to 13.71 M in the 1907.

Income, Expenditures and Net Yield. The income per hectare has risen (1867 907) from 44.03 M to 89.86 M; the expenditures from 36.9 M to 41.8 M, the net 1 from 26.77 M to 52.31 M (with normal exchange, about \$3.70 to \$4.20 per acre).

VI. GRAND DUCHY OF HESSE.

he directions and aims which are followed in formulating working plans are charac- ized by the words: "The management (p. 253) of the State and communal forests is e directed, with adequate consideration of the needs of the present, so as to increase yield (qualitatively and quantitatively) as quickly as possible to the highest possible unt. In order to attain this object, the aim must be to bring the actual increment earily as possible to the normal."

he most important measures for the attainment of the normal yield condition are:

y utilization of poor stands, choice of species adapted to the site, technically ect forestation, thorough care of the stand, and rational thinning practice. The st important prescriptions in the Instructions refer to:

The Construction of the Stand Table. The document most characteristic of the king plan bears the title "Stand Table and Management Book (Wirtschaftsbuch)" is drawn up according to the following scheme:

District and Compartment.

Wooded Area—ha.

Group.		Site and Stand Desc., Soil, Situation, Exposure, Species in Decimals of Stand. Justification of Management Hitherto.	Aim of Management, and Measures for next Decade.	Principal Species and Age.	Average Height of Stand and Site-Class.	Growing Stock: Timber and Brushwood According to Yield Table	
lit.	Area.					For 1 ha.	For the Group or Compartment
	ha. $\frac{1}{100}$					cu. m.	
1.	2.	3.	4.	5.	6.	7.	8.

Reduction Factor.	Actual Growing Stock in Timber and Brushwood for Group or Compartment.	Growing Stock in Over-wood Volume.	Current.		Estimate of Yield in Timber and Brushwood Expected in next Decade			
			Normal Increment	Actual Incr.	Main Yield.		Intermediary Fellings.	
			For next 10 Years in Timber and Brushwood on the Average Per Year and ha.		a) Over-wood Volume	b) Other Mature Timber Cut.		
			In the Group or Compartment.		Per ha.	In the Group or Compartment		
	cu. m.		cu. m.		cu. m.			
9.	10.	11.	12.	13.	14.	15.	16.	17.

The following explanations are also given (p. 255): Parts, within the permanent partments (Abteilungen) are segregated as lots or groups (Gruppe), which differ each other so essentially in site, species, age, growth, etc. that they must be under special treatment. The groups are designated on the maps by small Latin letters. The parts (as small as .7 acre) of the compartment are adapted by situation, size and shape to special management The organizer decides whether the parts are to be permanent or temporary. If groups are based on site, they are permanent; but if based on the condition of the stand they are temporary. These differences are in the course of time to be diminished or eradicated. The stand descriptions follow the rules of the Forest Experiment Stations. Measurements for the essential establishment and development of the stands are given in the descriptions.

objects of management (as the stand appears at the time of survey) are entered in the plans; as a rule the local officer in charge coöperates directly in drawing up the working plan. The "objects of management" are not, however, binding for all time; they may be altered to assist newly appointed officials and changes may be ordered at the time the working plan is drawn up, or be agreed upon at inspections. The urgently necessary measures of the next 10 years are to be briefly stated by the administrative officer. The mixed stands the main species determines the management. Height forms the important basis and measure of site classification. In every lot or group the average height of the stand is determined by measuring several stems of about medium diameter; on the basis of this height and age, the site classes are established according to the standard of current yield tables. The normal growing stock is also taken from the yield tables; the actual growing stock is found by multiplying the normal stock by a reduction factor, which like the full yield factor in Prussia is expressed by a decimal (p. 256). The current (normal and actual) increment, which appears in the stand plan, refers to that part of the total increment, which goes into the permanent stand. The normal increment is found by subtracting the growing stock volume of the main species (as found in the yield tables) at age (a) from that at (a—10) and then dividing the difference by 10. The actual increment is found by multiplying the normal increment by the full yield factor.

The Calculation of Growing Stock and Increment. In order to give the total normal increment and normal growing stock, a statement of the site classification for the future main species is required. The normal increment, arranged according to species and site, is calculated as mean increment at felling age. On the basis of the conclusions of such a statement the normal increment and the normal growing stock may be figured from current yield tables. The calculation of the normal growing stock is made under the assumption of regularly graded age classes (I. 1-20, II. 21-40, etc.) and the normal area of which is determined by their relation to the total rotation. The estimates of yield are made to the middle of the age classes. By adding the estimates for the different site classes, normal increment and normal growing stock for the different species is obtained. The total normal increment and normal growing stock is found by adding the figures for the different site classes. The age class table serves as a basis for the statement of the actual growing stock; the area and the actual growing stock in timberwood and brushwood is given for every age class. At the end of this tabulation, the areas and growing stock of each age class are compared with the normal age classes and the normal growing stock. The budget is based on the following:

The Protocol of the Council. After the preparation of the data cited above, a protocol of the council is taken down which is to be submitted to the ministerial division for approval. This must cover: the species to be planted or to be favored in the future, the rotation, the possibility of a uniform period of organization, the sequence of plantings, the present silvicultural method of management, any contemplated changes, the normal felling area and the formulation of management rules.

The Formulation of the Budget and the Method of Utilization. (Logging Practice). 1. **Felling Budget (p. 257).** A. **Utilization in Mature Timber.** The normal felling area forms the basis for utilization, covered by the working plan. If the stand conditions are regular, it is sufficient to draw up the felling plan for a decade. Irregular conditions may indicate the desirability of planning the expected fellings for two or more decades. Deviations from the normal fellings are to be mainly justified as follows:

a) *The Relation Between the Actual and Normal Growing Stock.* Present differences are to be diminished unless a change of rotation is contemplated. To determine the propriety of felling a growing stock surplus or of making up an existing deficit all silvicultural and financial conditions must be exhaustively considered.

b) *The Age Class Relation:* The growing stock of the 2 or 3 oldest classes is to be especially considered; if the actual growing stock does not differ essentially from the

normal and if an appropriate part of the stock is found in the 3 oldest classes sustained yield may be considered as assured.

(c) *The Relation of Fellings to Increment.* A comparison of the felling budget the actual increment gives an indication whether, in the next decade, a diminution or increase of the growing stock may be expected.

2. **Determination of the Felling Areas and Progress of Regeneration.** Areas of growth, where the increment differs most widely from the normal, should be selected first. Stands are chosen for the felling budget upon the following basis: I. Stands in need of felling: (a) Stands and parts of stands with poor increment, (b) remnants of high forest, improvement fellings, and clearing for roads, (c) parts of stands which must be sacrificed to establish a felling series; II. Mature Stands (p. 258); III. Questionable Stands. Great stress is laid on a regular felling series and a good distribution of fellings. Large areas of even-aged stands are to be limited as much as possible because of the dangers from storms, insects, etc. and to facilitate the distribution of wood supplies. The Instructions prescribe, therefore, the formation of short felling series with cross-roads, railroads, rides, roads, watercourses, and mountain crests, etc. as boundaries.

3. **Determination of the Wood Volume.** The following rule is of interest: The stands selected for the main felling budget for the next 10 years generally need to be cultered; the volumes of the felling budget can be based on yield tables and estimates. Errors in estimating (due to this mere approximation of the main felling budget) if they are established at the time of felling, may be corrected by changing the felling budget within the 10-year management period or at the close of the period.

II. **Secondary Fellings.** The thinnings (whose yields are entered in the tables mentioned) are listed in an area and volume budget corresponding to the main budget. The area budget is so made that about 1/10 of the total area to be thinned is cultered annually, so that the felling is extended equally over younger and older stands, and need be over stands of different species. The yield estimate is based on the yield tables, after carefully considering the actual conditions of the stand in question. Considering the difficulty of establishing and executing adequate thinning budgets, a plan has been made, that, at the close of the annual working plan, a compilation of periodically thinned areas must be prepared. If it is found that according to this statement, the secondary fellings are not progressing fast enough, the secondary felling budget must be increased accordingly.

5. **Mapwork (p. 259).** The stand maps made to accompany the working plan at the scale of 1:10,000 show the age classes by color, the species by tree figures, the boundaries by broken lines.

6. **Control.** An efficient control covers the total felling, main and intermediate timberwood and non-timberwood.

VII. GRAND DUCHY OF SAXONY.

The Preparation of Working Plans (including surveys and check of management) is assigned to a special bureau ("Taxation Commission") whose president directs the work. Assurance of a present and future sustained yield is considered of first importance in forest organization, provided forest production maintains and increases the fertility of the soil, and the highest yields are produced in the shortest possible time.

The subdivision into permanent management units (compartments) has been carried out in a systematic way; in the plains by a net work of regular lines and in the mountains via contours connected with the road system. The average size of compartments is about 62 acres, and lots, if adequate stand differences exist (which form the basis of the management), are segregated to a minimum size.

Stand volumes for the first decade are secured by special stock taking, which is done for each stand: number of stems, diameter, height, form factor, increment in diameter, basal area, volume and increment per cents. The results of the volume calculations are filed with the Commission. The forest experiments on yield are connected up with forest regulation; in fact the president of the "Taxation Commission" directs the e-

The method of yield regulation is the combined allotment, which was upheld in literature by Grebe, for many years the director of the Grand Ducal forest organization. Present it is only used in its simplest form, in such a way that the yields are only given for the first two periods. The main working plan is therefore to be formulated according to the following form:

Forestation:

[illegible]

The areas and volumes of the first (20-year) period are shown separately for the first and second decades. The timber yields in cubic meters are derived by adding the increment (up to the middle of the utilization period) to the present volume. The actual main felling budget is found by dividing the budget of the first decade by 10. Fellingings are regulated by area, but volumes are checked by local yield table estimates in special investigations. The control of fellingings and forestation is according to the following scheme:

[illegible]

II 20 Year Period. from to			III 20 Year Period.	IV 20 Year Period.	V 20 Year Period.	VI 20 Year Period.	Reforestation Area in First Decade.	Rules of Management
Felling Area.	Wood Yield.							
	per ha.	Total.						
ha.	cu. m.		ha.	ha.	ha.	ha.	ha.	

The volumes of actual thinnings are compared with the budget. Revisions occur as a rule every 10 years (p. 261). The policy concerning silvicultural methods, rotations as well as all conditions influencing the treatment of the forest must be clearly shown. The revised tables must show first of all the results of management during the preceding decade; next the plans for the coming decade. Otherwise the (working plan) revisions (which are similar in detail to those adopted by other states) depend on the changes which have taken place in the condition of the forest during the last decade.

Year.	Lot.	Areas.		Wood Yield.					Cultures.		Special Data as to Method of Felling and Cultures.	
		Clearings.	Intermediary Fellings.	Timber.	Fuel wood.		Main Fellings.	Intermediary Fellings.	Root-wood.	Area.		Costs.
					Wood.	Brush- wood.						
ha.	cu. m.	cu. m.	rm.	ha.	M.							

VIII. ALSACE-LORRAINE.*

When formulating new working plans (for forests for which there are no plans if there are plans, after the expiration (p. 262) of the 20-year period, after essential changes in area, after considerable overcuts due to windfall, insect injuries, etc. when changes to other silvicultural methods are contemplated) a preliminary plan (which must include the map for subdivisions and road system as well as regulations regarding the methods of management and rotations) is drawn up by the revisor; this is examined by the Forest Inspector and finally accepted by the Minister.

The most important regulations for the formulation of working-plans are:

1. **Subdivision.** The formation of permanent management units (compartments)

* See also the discussion in "Studies in French Forestry" already cited. German Forest Management in Alsace-Lorraine, now restored to France, is of special value to the student of regulation, especially when compared with French technique.

ected up with the road system. The area of the compartments must not as a rule be less than 25 to 37 acres in conifer stands, or 37-50 acres in broadleaved stands. Coppice management under standards are subdivided into yearly felling areas as the local basis of management. In communal forests (as was prescribed in the ordinances of Colbert) the fourth the area is first to be set aside as a reserve. No binding rules are given for the formation of lots. In large forests (if several species are concerned) the smallest lot is 2.5 acres, provided a good boundary is possible, otherwise 5 acres where stands are being regenerated $2\frac{1}{2}$ acres or if old timber is clear cut The lot corners must be marked locally by stakes and non-continuous ditches and entered on the maps. The compartments are labeled as in Russia with Arabic numbers, fellings in coppice under standards and selection forests with Roman numbers, lots with small Latin Letters, while non-forest soil is indicated with German letters. With new subdivisions (p. 263) the numbering of the compartments and lettering of the lots is from the northeast towards the southwest, so that compartments and lots always bear higher numbers or later letters towards the wind direction.

Surveying and Mapping. Survey work is as a rule limited to changes in interior divisions, since usable maps exist for the whole country. After the survey of a compartment and lot lines, highways, roads, and water courses, etc., the special map (or office map) is to be brought up to date by the working plans officer. With the projected special map as a base, a control (Uebersicht) map, which differentiates the species by color, is to be made on the scale of 1:25,000. The dates of utilization are given for the areas assigned to the (I) and (II) period. The symbols used are: (I) first period areas, (II) second period, (I. II.) areas to be regenerated within 40 years, (Pr.) selection stands, (S.) scenic forests; areas designated for oak reproduction (at least $\frac{1}{3}$ acre in area) are outlined in red on the management map and must be marked in the forest.

The General Description of the Revier digests the characteristic features of management regarding the general condition of the revier (as regards ownership), boundaries, survey, etc., site conditions (climate, configuration, soil); the occurrence and preservation of the main species; the previous management and its results; future management, especially the species, methods of silviculture, rotation; formulation of management regulations for fellings, for regeneration and development of the stands, location of the road system and subdivisions; the wood market, secondary uses, etc.

Special Description of Site and Stand. Site classes are given as a rule (if the maps do not show decided differences), for the whole compartment. They are based on the yield capacity (as compared with existing yield tables). Descriptions of situation, soil, and stands are as agreed upon by the Union (p. 264) of Forest Experiment Stations. The mineral content of the soil, its freshness, depth and humus content is judged by sample borings; stand descriptions are brief to the exclusion of all unessential or self-evident statements.

Segregation of Age Classes. Age classes are formed for each species; when different ages occur the areas are separated, especially stands under regeneration where the wood volume is divided into old timber and young growth.

Measure of Utilization and Periodic Area Division. The normal periodic area is given as a measure for the periodic cut in the present management period. If all the stands are to be managed under the same rotation, the normal felling area for a period is obtained by multiplying the area by 20r. (where r = rotation). If several rotations are used, the normal periodic felling area is similarly determined for each species separately; the total felling area is then found by adding up the areas for each species. The stand volumes for the first period (in which regeneration cuttings have begun) are placed in accordance with the age classes. A further allotment of stands for the III, IV, V, and VI periods is not made; these are simply listed in the column "Later periods." In selecting the stands for the periods, their age and vigor must be taken

into consideration. In conifer stands the formation of short felling series is recommended. The rigid allotment method is no longer in use in Alsace-Lorraine.

7. Scaling and Listing of Wood Volumes. Because of large contiguous stands of old timber and the long regeneration period (p. 265) the periodic area . . . usually includes two periods. The volumes of all uncut regeneration fellings (I hiebsreste) of the (I) period as well as the mature and nearly mature stands of the (II) period are usually calipered. In regular stands of the (II) period the growth stock is approximated by sample plots The volume of the second period is subtracted from the totals of the two periods increment (calculated at the middle of period) added to determine felling budget

8. Felling Budget. This is obtained by dividing the totals of the volume measurements by 20. The felling budget, calculated in cubic meters of timberwood, is separately for the main and secondary fellings, by the four species groups: oak, beech, other broadleaved trees, conifers. In the communal forests a quarter of the area is held in reserve from the calculated main felling.

9. Regulation of the Yield in Coppice and Coppice Under Standards. The yield cut in these forests is arranged in regular sequence in flooded districts in the direction of the water flow. In coppice under standards the standards are calipered and (p. 266) calculated by age classes

10. Regulation of Yield in Selection Forests. The felling budget is calculated from the actual increment and according to the relation of the actual to the normal growth stock (by the K. Heyer formula, felling budget = actual increment + or — difference of actual and normal stock divided by "equalization" period). To get the actual growth stock all stems 3 inches and over are calipered. The actual increment is (p. 266) determined (p. 266) by special investigation on stems of different diameter classes. The normal growing stock is figured by the formula rotation $\times$ mean increment (mean felling age) divided by 2 (or mean increment at felling age multiplied by half rotation). The length of the "equalization" period is determined in each case. The cutting cycle is usually short, i.e. 7-9 years.

11. Forestation and Road Building Plans are always included in the working plan. The Forestation plan includes; formation of stands, nursery work, seed collection, selection of felling areas and trees, emphasis is laid on the care of the soil irrigation and drainage protection ditches and leaf catches. For the planning, layout and maintenance of logging roads detailed and careful directions are given.

12. Working Plan Revisions take place in the middle of the 20-year period. The kind and extent of the work to be undertaken is dependent on the demands which arise from the working plans, and the changes which have occurred through management or through outside influences, in the first half of the management period. These include; changes in area, annual felling volume and its comparison with the working plan, compilation of the final cuttings and comparison with the estimated yield, extraordinary fellings, secondary yields, execution and cost of forestation, changes in conditions, influence of secondary logging, the road building, etc.

IX. AUSTRIA.

The most important technical instructions for the organization of the Austrian forests concern:

1. Subdivision of the Reviere (p. 267) begins, where necessary, with the segregation of the protection and "ban" forests. Special protection belts are set aside where the forest reaches timber line The commercial forests have: management class, felling series, compartments, and lots.

(a) *Management Classes.* Different working groups are formed for different kinds of contiguous forests because of differences in: transportation or market, method of treatment (high forest, coppice, etc.), method of cutting (clear cutting, natural regeneration, selection forest, etc.), rotation, or existing limitations of management.

(b) *Felling Series.* The working groups are divided (where sequence of felling

Survey and Description of Forest Conditions. (a) **Preparation of Yield Tables.** It is generally prescribed in the organization of State forest reviers that yield tables will be made for the different methods of treatment, species and site classes. These are based on carefully selected and combined sample plots (p. 269) The data required are as follows:

[illegible]

b) *Stand Descriptions* contain: (1) Statements on the condition of the soil (subsoil, top space, humus contents, cover) and situation (slope, exposure, etc.). (2) Species, structure, The space each species occupies is expressed in decimals. (3) Mean, minimum, and maximum age is given. The compilation of age classes is given in the age class tables separately for each

working group The areas under regeneration are entered in the column "Regeneration Class." The areas are also distributed as accurately as possible in the columns: "(old timber," young growth," and "openings or clearings)" (p. 270).

4. **Index of Yield.** The productivity is shown by: (a) The stand mean; (b) total basal area; (c) The site class. To this must always be added the species which it relates. In mixed stands only the main species is considered; (d) Percentage stocked

5. **The Growing Stock; (a) Main Stand**

Secondary Stand (*Zwischenbestand, Nebenbestand*). This includes all suppressed trees and those that suppress the main stand (therefore to be removed or resulting in undue openings). Secondary stand volumes that probably can not be utilized in the coming decade, are not given in the estimates.

6. **Mean Increment at Probable Felling Age** uncertain plantations omitted

7. **The Volume Increment Per Cent**, calculated according to the formula $i = \frac{(M-m)}{(M+m)}$

$\frac{(M-m)}{(M+m)}$. M and m = volumes n years apart. The volume and increment calculated in young and medium aged forests are as a rule from yield tables; in nearly mature and mature stands, on the contrary, an accurate calculation of the growing stock is always made. Unevenly stocked areas less than 5 acres in area, are completely calibrated. In regular stands sample plots (5-10% of the stand area) are selected in suitable locations (p. 271). The volume calculation is based on mean trees. All volume and increment figures are compiled and appended to the working plan.

8. **Quality Increment Per Cent**, calculated according to the formula $b = \left(\frac{200}{n}\right) \left(\frac{Q-q}{Q+q}\right)$

in which $Q - q$ = average net difference of value, $Q + q$ = the sum of values of average cubic meter , n = the number of years which the stem requires to pass from one class to another.

9. **The Index Per Cent** (after Pressler) calculated according to the formula $W = \frac{H}{H+G} (a-b)$, where a = volume per cent, b = value per cent, H = the average value of the stand, G = base capital (soil, administration and forestation capital).

10. **Notes on the Management of the Stand** (time and method of utilization, clear-cutting, thinning, pruning, reforestation, drainage, etc.).

General Description. This records the current natural, legal, political, technical, commercial, financial and organization conditions, and includes especially: the administrative unit (separated into forest and non-forest soil), how the non-forest soil will be used, property and legal conditions, boundaries, agricultural and water conditions, topography and soil, situation, climate, atmospheric influences, conditions, their history and management up to date, timber volume and money secondary uses, hunting and fishing, timber prices in the forest and at the markets, statements regarding personnel, etc.

3. **Determination of the Felling Budget.** This is given for a decade. The production is classified as main fellings, intermediary fellings and accident fellings.

All yields (p. 272) from the felling areas (selected for the next management period) belong to the main cut, as well as those accidental fellings that necessitate reforestation on at least .8 acre. Timber from windfall, snowbreak, frost or insect damages, stolen timber recovered are entered separately as accidental fellings. The yield from weedings, thinnings and other improvement fellings are classed as secondary fellings.

(a) **Main Felling.** The normal felling area forms the basis for the allotment for the next management period The determination of the rotation is based on the following policy: If there are no forceful reasons (due to transportation conditions or market) for the retention of the present rotation (especially if very high), the

tion should aim at securing an adequate interest rate on the capital investment. These stands are considered mature where the index per cent has sunk below the present rate of interest (provided fellings are possible, with due regard to the rigid demands of the felling series).

unquestionably the following stands must be allotted (for utilization) to the next period: necessary severance fellings, safety strips, irregular stands with low increment whose speedy regeneration is desirable because of low increment and poor soil conditions), and finally those stands which must be sacrificed to obtain a proper felling series. In irregular stands the felling areas are to be corrected The Instructions prescribe: "In determining the main yield in the annual management plan for a working group, on the basis of the age class table, it must be stated whether mature stands or stands capable of being cut and younger age classes (to be cut later) are sufficient, whether the cutting of mature growing stock is to be curtailed (and if for how long), or whether, on the basis of general management rules a more rapid utilization of any existing volume surplus is desirable or justified (p. 273). "The time at which the creation of the normal age classes is to be attempted, is to be based on expert advice. The budget justifies the determination of the normal felling area by a summary of past fellings and the influence which these fellings have had on the development of the age classes. The age class conditions are therefore shown for a considerable period." "These comparisons and considerations," say the Instructions at the close of this section, "will lead to a final determination of the felling area; and the calculated volume (increased by the current mean increment up to the middle of the period of management), forms the volume budget for the decade. The strictly sustained yield is not necessary for each working group, except in those forests which are heavily burdened with servitudes.

b) *Secondary and Accidental Fellings.* Secondary fellings are classified as cleanings, thinnings, and fellings of seed trees* in young stands. The secondary felling budget is found by summing up the proper merchantable volumes (estimated for each in the stand descriptions). The estimate for accidental fellings for each working group is summarized according to the records of past years, or according to experience.

c) *Estimate of Yield in Selection Forests.* Since the selection forest aims primarily at the protection of the soil, and since a regular sale of the cut is frequently unfeasible, the determination of a sustained yield budget (according to the definite established method) is usually given up and the felling budget is estimated by judgment.

Control and Revision. To show the changes which have taken place in the course of the management period, a number of records are kept by the administration; these control the estimates of the working plan and its execution, and serve as a basis for future revisions. Of special importance is:

a) *The Journal* (p. 274) which is similar to the general part of the Prussian ledger (Hauptmerkbuch). In it, are recorded: all changes occasioned by fellings contrary to plans, changes in area or boundaries, in transportation and communication, important injuries by man, natural phenomena, fires, etc.; also statements about hunting and fishing, labor conditions, statistics regarding volume and financial results, works for the control of torrents, forest experiments, personnel, etc.

b) *The Management Book* (like the Prussian Control Book and the special part of the ledger) is divided into two parts. The first gives for every single lot (Kontrollparterre) the cut of material in round numbers (divided into timber and fuel wood, hard and soft wood, main, secondary and accidental fellings) together with the respective felling areas; also the reforestation carried out (divided into sowing and planting) as well as drainage data and the care of the felling areas and stands. The second part

So called "overholders" are not misshapen trees stealing light and food from the crop but instead are trees held over from the former crop to furnish seed.

contains the annual compilation of fellings from the whole administrative district, the check of fellings (actually cut) together with their estimates.

(c) *Statistics* concerning: changes in ownership, cut of stands (compared with estimate), fellings (compared with the volume and area given in the felling but not prescribed in the plan, forestation and cost, income and expenditures, material money results, etc.

There are 2 kinds of revisions: (1) intermediate revisions, which become necessary in the course of the management period, due to unforeseen conditions (windfall, injury by insects, etc., and (2) regular periodic revisions, which are undertaken the last of the decade (for which the working plan was drawn up). The most important problems of the periodic revision are: In the first place an investigation as to whether the working plans have been closely adhered to in all parts, whether and to what extent the deviations have been justified, and how far the regulations of the old working plan have been proven correct in detail and as a whole. Secondly, the correction of the existing geodetic and mensuration data (or such new data as may be required for the next decade's working plan). Thirdly, the preparation of the working plan for the next decade (p. 275). The intensiveness of the revisions depends on local conditions, but as a general rule the work must be done according to the "Instructions for Forest Organization."

X. FRANCE.

See "Studies in French Forestry," by Theodore S. Woolsey, Jr., John Wiley & Sons, 1921, pages 206-261, 469-495, and 500-534, for a discussion of regulation in France.

APPENDIX A. (b) FINANCIAL ROTATIONS (FROM ENDRES).

A. Concept and Reckoning. By financial rotation we understand that period which, according to the soil rent theory, will produce the greatest land rental. It then falls at the time when the proceeds from the land are greatest.

a. *The financial rotation of single stands.* If the stands are normal one reckons the soil rent for the several age classes (considering together those having similar earnings and cost) and the financial rotation is fixed at that age which indicated the greatest land returns. If it is a case of fixing the rotation for a stand not yet planted then one has to have interest tables to guide him in the work of fixing the rotation period.

It is obvious that the rotation period found in this manner is valid only so long as those data, which has been used to figure out the rotation, remains unchanged. A permanent change of these conditions also causes a change of financial rotation.

Since there is no cost of administration and management the cost is very small, owing to the fact that it would have a long drawn out effect upon the final interest, suffices to state, for the final rotation, the following formula:

$$B_u = \frac{A_u \text{ plus } D_u \cdot \frac{1}{i} \cdot \frac{1}{Op^u - 1} \text{ plus } \dots}{1, Op^u - 1}$$

Where B = Capital land value.

A = Yield.

D = Value from thinnings.

u = Years in rotation.

a = Time of thinnings.

Or, when the thinnings that have been computed ahead are expressed as a percentage of the yield, we have

$$B_u = \frac{A_u \cdot \frac{1.0d}{i}}{1, Op^u - 1}$$

The financial rotation or better still the rotation in *abnormal stands* is arrived at.

(a) Through figuring the largest future return.

(b) Through figuring the growth per cent.

in both cases we consider the maximum normal use of the forest soil for continual
If we contemplate putting the soil to other uses such as farms or sale then we
figure in the higher value.

This formula could also be used to figure future value of *normal* stands. The largest
re stand value of normal stands is figured on that rotation in which the soil rent
mination and the per cent earned will at the same time be equal to the rate of
rest.

owing to its simplicity the growth per cent is used in preference to the method of
est future returns.

The financial rotation of the working circle. In order to approximate the area on
ch money returns will be forthcoming yearly, and to make sure of the area to be
ned the forest working plan must set forth some definite time limit as a working
is, that will suffice for the timely or orderly use. This time limit will serve a
eral rotation period of the working circle.

Because the largest forest is never made up of equal working stands it is impossible
figure rotation by a mathematical formula. It is more likely to be the average
ncial rotation of all single stands, from which again the older marketable wood
st be given primary consideration.

We cannot measure the influence which the general rotation will have on the single
nds. We cannot characterize it as Kraft has done.

The length of the general rotation is influenced by the financial working of the single
nds. The financial producing power of the stand depends on the manner of handling.

. . . . It does not all depend on whether the stand has a general rotation that
oo long or too short; whether the stand is too old or too young; whether or not
age of the stand surpasses the general rotation; or whether the stand is growing
good agricultural soil. These are all considerations but they do not determine the
ation period. *It is, moreover, through the use of growth per cent that we get at the pro-
ing power and usefulness of the stand.* This is arrived at through the measurement of
product. All stands that cannot come up to the desired quantity of products should
be considered for felling; they deserve consideration on account of their growing
dition for the building up of a good later cut.

In normal forests the financial rotation falls at the time when the formula gives a
ximum result.

plus D_a plus . . . $D_q - (c \text{ plus } uv \text{ plus } uNO. Op)$

u

is period of time culminates with the soil rent period, because:

$- D_a - . . . D_q - (c - uv) - N. O. Op = (B_u \text{ plus } N) O. Op - N. OOp = B_u$

u

N is to be understood the soil rent value of the figured rotation " u " or, the value
the soil under normal conditions. Therefore it is shown that the use of the first
mula is a roundabout manner of determining the financial rotation; having to figure
t the soil value for different rotations it is useless to figure financial rotation by
first formula.

In recent times, Martin has used the first formula however with certain changes. He
ed instead of expected value or cost value the value it would have if of actual use.
is is theoretically unreliable. Nothing is gained thereby from a practical standpoint
the determination of the actual value of usefulness of young stands is very difficult
d, more often, impossible.

3. The Length of the Financial Rotation. *The length of the financial rotation is influ-
ed by all of the following factors which affect the climax of the soil rent. Of the afore-
mentioned facts it is important to note (p. 72). Of great influence is the rate of interest
d. For high interest rates you figure short rotations, for low rates long rotations*

That you exercise care in the general handling and forest management of the two

categories of soil;—namely, *profitable* and *unprofitable* soil. For the question of p through and continuing the financial rotation only the *productive* soils can be given *sideration* as forest soil.

In soils belonging to the unprofitable category you figure for pure, even-aged, stands with a working interest of 3% a financial rotation of from 60 to 90 years. absolute length of the rotation depends principally upon the value of older stands the younger stand. *The longer the value continues to increase the longer will be the rotation.* Of primary importance is the *quality* increase. Should the quality increase soon and should it not be possible to continue the quality by clearings and liberation cuts then the rotation will be much lower.

In dense even-aged stands the financial cutting period comes later with poorer soil and growth. In both cases the quality increase of the wood is concentrated on the stand ages.

From the measurements by Oberforster Schulze (Allg. Forst und Jagd. Zeit. p. 329) the financial felling age in the Royal State forests using $p=3\%$ is shown in the following table:

SPRUCE.

On	2%	of the area	=	1,200	ha. in the	55- 60 years
"	9%	" " "	=	5,700	" " "	60- 65 "
"	25%	" " "	=	10,500	" " "	65- 70 "
"	21%	" " "	=	14,300	" " "	70- 75 "
"	21%	" " "	=	13,800	" " "	75- 80 "
"	7%	" " "	=	4,800	" " "	80- 85 "
"	11%	" " "	=	7,300	" " "	85- 90 "
"	2%	" " "	=	1,500	" " "	90- 95 "
"	2%	" " "	=	1,200	" " "	100-10- "

(The highest rotations fall on the ore mountains of Saxony.)

PINE.

On	7%	of the area	=	1,500	ha. in the	50- 55 years
"	20%	" " "	=	4,400	" " "	55- 60 "
"	26%	" " "	=	5,600	" " "	60- 65 "
"	19%	" " "	=	4,000	" " "	65- 70 "
"	6%	" " "	=	1,300	" " "	70- 75 "
"	12%	" " "	=	2,600	" " "	75- 80 "
"	10%	" " "	=	2,200	" " "	80- 85 "

For the spruce stands of the Thuringerwalder, Forstmeister Schmidt shows the lengthened time of the financial rotation for the different soils, gotten at by figuring the growth per cent. Figuring $p=3\%$, the table shows the following average rotations per cents:

for 87-92 year old stands of	II soil 2.74%
	III soil 2.89%
	IV soil 3.28%
for 95 year old stands on	II soil 2.86%
	IV soil 2.97%
for 97-105 year old stands	II soil 2.66%
	III soil 2.57%
	IV soil 3.14%
for older stands	II soil 2.60%
	IV soil 2.79%

Wimmennaurer figured in three different forests of the Grand Duchy Kissen for pine II and III stand classes; rotations from 60-70 years when $p=2.5\%$. He remarks that by introducing liberation cuttings many rotations are reduced from 120 to 100 ;

berforster Walter figured, in his forest Grebanare, the following growth per cent
es for the pine:

Allg. Forst und Jagd., 1888, p. 202.)

	60 years	80 years	100 years	120 years
p = 2%	\$149	\$163	\$153	\$131
p = 2.5%	100	104	93	76
p = 3%	70	68	58	46

3. **Estimating the Financial Rotation.** For the unprejudiced forester it is needless
say that it is practically impossible to set a definite year for the determination of
financial rotation; We can be satisfied if we are able to figure the
e of cutting within a ten-year period we should not speak of *one year*
of the *period of financial cutting*

The computed financial rotation is then an indication which serves to tell the time
greatest soil rent according to the given conditions. It indicates a possible point
it should not be taken as the only and inflexible program for regulating the *growth*
cent. It endeavors to realize from the soil the measurement of its productiveness
to determine the largest obtainable soil rent. The means by which this is secured
not only in obtaining and carrying out the financial rotation but in harnessing and
essing the productive strength of the forest soil. The proper distribution of species,
ional systems of management carried to old age, making use of increased growth
e to light, reproduction, understory, growing valuable species,—these are the means
hich the forester can apply and they must be made use of by him in obtaining the
ghest possible soil rent. (See the work by G. Kraft, dealing with the "Management
the Soil's Productive Power,"—1890, also,—"Consideration of Forest Valuation,"—
87. The fundamentals given there are gold nuggets of the German literature and
ery thinking forester should take them to heart.)

When the existing stands are not capable of producing a large enough soil rent (or
en in order to obtain a reasonable soil rent a very short rotation is needed) then
e means of remedy lie in building up and improving the stand and in part through
plying modern technique as a guide in selecting certain kinds of species. These
onsiderations are more fully brought out in the following viewpoints.

(a) First consideration for quality are: Clearness of bole, little taper, soundness of
e wood If stocking was incomplete when the stand was started, if the
ung stand was grazed, if neglected in the thicket or polewood stage, or if damaged
atrocious cutting, or abused through unregulated cuttings or thinnings,—these stands
ll show no improvement in stocking and will produce chiefly scrubby, poorly formed,
ranchy and unhealthy trees with excessive taper

Such stands are not capable of a high soil rent; on the contrary a low rate of
crease in valuable timber is the result. The sooner we clear off such undesirable
ands and replace them with more worthy species,—and thereby utilize the full pro-
ective power of the soil—the less will be the loss to the forest owner (Endres
ow emphasizes the need for raising *timber* rather than fuel and poorly shaped poles).

(b) It must be concluded that spruce and fir are best grown for timber purposes.
pruce and fir have their principal use as lumber and dimension stuff. It is now a
iversal fact in the European market that there is no demand for boards wider than
4 inches. Squared timbers 13.8 inches in diameter command comparatively low
ices; sizes larger than this have practically no sale. The average price paid for
pruce timbers in the Royal-State forests during the ten years 1880-1889 per cubic
eter:—

Average diameter	Per cu. m.	Per 1000 board feet	Increase in price per cu m.
5.9 inches	\$2.50	\$10.00	....
6.3 to 8.7 "	3.07	12.28	\$0.57
9 " 11.4 "	4.02	16.08	.95
11.8 " 14.2 "	4.65	18.60	.63
over 14.2 "	4.75	19.00	.10

Timbers over 14.2 inches in diameter as compared to those from 11.8 to 14.2 in diameter have a quality increase of only \$.10 per cubic meter. The largest increase in price is in the timbers between 9. to 11.4 inches.

Regarding the sale of construction timber the conditions are not much different. Industries of modern times demand *iron for the heavier uses*. The buildings that formerly used heavy fir timbers for girders now use *metal*; for other uses, where formerly strong beams were required, they *obtain the same strength by joining several pieces together*. It becomes necessary for the mills to cut out of large logs smaller sized dimensioned timber and boards according to the sizes called for.

Oberforster Karl observed the same conditions for the Alsace-Lorraine and Luxembourg markets. It is interesting to note that the fir (the so called "Holland wood"), which was raised purposely in the Black Forest for heavy timbers no longer is demanded, already there is an over-supply

"These latter, or so called standard sizes are the most saleable and can be disposed of in large quantities. In view of the fact that the *increase in growth of the older trees at 120 years will be at the highest only 1.5%* and the increase in price from standard grade to "Holland wood" (largest size) will be at the most \$.25 per cubic meter, it can be easily figured what will become of the profits if we raise large sized fir timbers . . .

The practice of growing large timber can only be continued for *pine and oak*. *these timbers you can command a high price and they are sought after But it is not to be believed that the increase in quality by raising large timber of these species will compensate for the higher soil charge*. In connection with the increase in price that is achieved you have a longer producing period to consider. Only in case you can handle the forest through thinnings that the larger timbers are produced in reasonable short rotations is the growing of such material possible. It is probably only possible on good soils and in connection with a two storied forest.

(c) Pure beech stands are not suitable for earning reasonable financial returns.

Up to 1840, pure *beech forests* were found in great abundance due, primarily, to their prolific natural reproduction. The beech was highly prized for its *fuel value* and one would have thought that during the development of the railroads and *within a short year period coal would replace the wood as fuel*. The later attempts to encourage the growth of beech for lumber have been unsuccessful.

The per cent of lumber produced (by pure beech) is very small, *only 20% at the best* and then the lumber prices are not much above those received for cord wood. In fact, an exceptionally clear piece of beech lumber will not be worth more than a similar sized piece of soft wood. Where the beech thrives best are good sites for softwoods and they will give a proportionally larger yield. If softwood is the primary species, beech can be grown as an understory and, owing to the beneficial effect on the soil, tendencies to cause a better development of the bole in the softwoods and remain in the hardwoods, it would raise the income of the stand indirectly.

"In such a practice one should not forget that the *beech is used only as an improvement to the dominant species which earns the highest soil rent*. In other words it is a means to an end. Through proper forest management it is possible to restrict its development on a particular natural site

APPENDIX B. GROWING STOCK AND YIELD, HARVARD FOREST.

The ascertainment of the annual yield, or total amount of saw timber to be produced annually from the Forest was based upon a rough consideration of area, age and volume. In the beginning only those stands were reckoned with which contained more or less of white pine, since hardwood timber was comparatively unprofitable, and yield tables applying to it were not available. The rotation and the mean annual increment for the whole area were determined from a yield table for white pine made by L. Margolin and published by the New Hampshire Forest Commission in 1901. Since quality increment in most of the pure pine type is unimportant, the rotation for the bulk of the Forest was fixed at 60 years which is not far from the point where

an annual growth in volume culminates. For arriving at the amount of the annual increment, the preliminary field work supplied the following data: a total stand of saw timber amounting to 10,500,000 ft.; a tabulation of areas according to type and age. Being almost wholly second growth the stand was everywhere classifiable into blocks of uniform age. The growing stock could thus be summarized in three periods of twenty years each covering the duration of the rotation. The mean annual increment, as derived from the yield table, was found to be approximately 250,000 ft. From the summary according to age and area, it was possible to determine in which periods of rotation, as compared with the normal representation of age classes, the growing stock was deficient and by how much. Considering the total volume of the stand and the surplus of volume in the third period, the theoretical allowable annual cut would have been about 325,000 ft. On account of the lack of tried silvicultural methods and the need of a good reserve of sizable timber for future scientific purposes, it was decided to put the annual cut at the conservative figure of 250,000 ft. or the annual increment of the pine-bearing lands of the forest. The succeeding cuttings in mature timber have been kept for ten years at this figure and a total of 2,500,000 ft. of lumber have been marketed. A reassessment of the growing stock and increment was undertaken in 1919. As a consequence of the absolute increase in productive forest area due to the planting of blank land and to release cuttings, and due to the inclusion of hardwood stands now merchantable but omitted in the first computation, the annual increment, exclusive of hardwood, is now found to be 380,000 board feet and the total volume of the growing stock 12,435,000 board feet. For additional data see Harvard Forest Bulletin No. 1, 1921.

APPENDIX C. EXAMPLE OF A PRELIMINARY POLICY STATEMENT FOR INYO NATIONAL FOREST.

The following is a discussion of existing conditions and the future timber policy of the Inyo:

Dependency and Local Demand: In the absence of transmountain transportation against which the high Sierras would seem to constitute a permanent barrier, the only local timber supply available for Owens Valley and vicinity is embraced in the Inyo (Mono Mills Block of the Mono National Forest).

The dependency area is defined as Owens Valley north of Owens Lake, Deep Spring and Fish Lake Valleys, and the mining camps in Nevada north to and including the mining camp of Candelaria. The bulk of the population of this area is located in the northern part of Owens Valley in the vicinity of Bishop and Big Pine, Bishop being the logical center for manufacture and distribution. The Southern Pacific narrow gauge railroad would make possible distribution to the entire population with the exception of a few ranchers in Fish Lake Valley and Deep Spring Valley. The dependency area has a population of 5,550 people with a present annual use of 4,000 M ft. of sawed material and 3,000 cords of fuel, fence posts and other similar cord materials. All cord material and approximately 15% of 600 M ft. B. M. of sawed material was supplied from the Forest, the remaining 3,400 M ft. B. M. sawed material being supplied from shipped products largely from the Truckee region.

No material increases in the use of cord material is anticipated in the near future. The Southern Pacific Co. is contemplating standard gauging the present narrow gauge road through Owens Valley, which would probably lead to cheaper coal, with the result that less wood would be used as fuel, which decrease would probably in a short period of years be compensated for by the increased demand due to increase in population, further division of ranch property, etc.

The present demand for building material will probably remain more or less constant for a number of years. There is, however, a rapid development in the fruit industry apparent in the near future which will probably increase the demand by some two million feet of box material within the next fifteen to twenty years. According to

figures obtained from Mr. Dixon, County Horticulturist, the present use and increase for the next five years will be as follows:

Boxes of fruit shipped during 1920 (all fruits)	35,000 boxes
Estimated for 1923	200,000 "
Estimated for 1925	300,000 "

Also the shipment of honey from the Valley during 1920 required 10,000 boxes, making a total requirement for 1925 of at least 310,000 boxes, which it is estimated would require about 2,000 M ft. B. M. of box material in the rough.

When taken into consideration that the available stand of timber runs at least 100 ft. of box and shop grades, this rapidly growing demand for box material is very fortunate as making possible practically 100% utilization of the entire product, a large percentage of which could not otherwise be utilized locally. In view of the above statement it would appear that the local demand for lumber products within the dependent area would be increased to at least 7,000,000 ft. within the next twenty years, possibly amounting to that much as an average for the period.

Available Supply of Commercial Saw Timber: The supply of commercial saw timber is confined to the northern portion of the Forest, the Casa Diablo block, the Mammoth and Summit blocks; the total stand according to cruise of 1907 by Mr. Eldridge is 670,000 M ft. B. M.

Timber cut during the past season showed an average age of approximately 40 years, which if taken as a basis of rotation would indicate that the local demand would exceed the annual yield of the available stand within the next twenty years.

Condition and Accessibility: The entire stand of timber is largely mature, the Mammoth Block particularly being over-mature as indicated by flat and spike tops and other indications common in an aged stand. Also this block shows unmistakable indications of a more or less general insect infestation. (Dendroctonus, according to reports by Mr. Hopping.) The only sawmill on the Forest is also located at the south edge of this block, being operated during the past summer to the extent of 622,000 board feet cut. The State Highway, which has been greatly improved during the past few years, connects this block of timber with Bishop, the distance being 48 miles from Bishop to the present plant. The Casa Diablo block is approximately 20 miles nearer to Bishop than the Mammoth block, but besides being a much younger, more productive stand which should not be cut at the present, is also shorter, poorer grade timber and though a shorter distance from market, the road is such that it is doubtful if transportation costs would be less than from the Mammoth block. Several attempts to market local lumber in competition with shipped in products were made prior to the past season apparently being the last attempt, which was by the Home Lumber Company. The reason for this seems to have been due to three factors:

1. There was no market for box grades and no means provided for their manufacture.
2. Road conditions were extremely unfavorable as compared with present conditions and the motor truck as a means of transportation had not at that time developed to any extent, making its use impracticable.
3. The low prices of lumber prevailing at the time.

Present operators, F. M. and A. W. Hess, fully recognize the fact that to make their production, which is 50% box and shop grades, it will be necessary to provide means of manufacture in order to market those grades at a profit. The transportation problem has been greatly reduced through improvement of the road by the State, the development of the motor truck as a means of transportation, and it is figured by Hess Brothers from the past season's experience that it will cost approximately \$100 per thousand under present conditions, as cost of trucks and operating expenses on freight their product from the mill to the Bishop yard. Also the present prices of lumber would justify a much greater expenditure to place the lumber on the market than was the case at the time the Home Lumber Company failed.

about \$.13 per acre with 7/10 of a cent extra for office. The extra cost of management plans (working plans) is estimated at \$.02 per acre above "preliminary timber survey work" The proposed rotation is 120 years, the net area 160,500 acres, total merchantable stand 2,870,000 M feet of which 75% to 80% is cut at the first ing. The loss from the decadent trees is considered offset by the growth in younger age classes. If the cutting cycle is 60 years, cut = 36 million; if 50 years, 44 million; if 40 years, 55 million; if 30 years, 73 million. The timber is extremely decadent. A 40-year cutting cycle "is about the shortest period of return that would give a sufficient stand to justify profitable logging"

There are included within the confines of the proposed initial sale area to the Fruit Growers the greatest portion of the most decadent stands and also a body of timber which is the most isolated and the poorest in quality of any in the working circle. The management for a rapid cut-over applies more particularly to this area than to the remainder of the working circle. A suggested compromise would therefore be to make an initial sale to the Fruit Growers upon conditions that would apply the conservative management practice that cuts about 80% of the merchantable timber and which would give an average annual cut of 40 to 50 million feet and at the termination of this sale, make a second sale reducing the cut to about 25,000 M feet which would be commensurate to a strictly sustained yield. It is believed that this compromise plan adequately protects the best interests of the Forest Service and fulfills the primary object of management to harmonize best the prescriptions of silviculture, sustained yield, and good economics. I therefore recommend the adoption of this plan."

District VI. Portland. According to Hanzlik:

Thus far in my calculations regarding the sustained yield, I have used what may be called the arithmetical method, checked by some of the standard formulae, Von Mantel's and Hufnagel's coming about the closest, although I consider that both of these give a high cut from our present type of forests in the Douglas fir region. It is difficult to explain clearly the arithmetical method used; it is what may be called a "cut-and-leave" method starting with a cut based on one of the above formula and then carrying through a rotation or two the theoretical stands resulting from a decrease of the mature stand and an increase, based on standard yield tables, in the present immature stands and the cut-over areas as development proceeds.

As an illustration, using the North Santiam Working Circle, Von Mantel's formula $V = \frac{Y}{\frac{r}{2}}$, we get $Y = \frac{4,000,000 M}{40}$, or $Y = 100,000 M$ feet B. M., basing the cut on a stand of 400,000 M feet and an 80-year rotation.

Hufnagel's formula takes into consideration the increment from the immature timber, in this case we have the following to start with: $V = 4,000,000$ feet B. M. (mature timber). Immature growth:

31,000	acres	80	years	old.
6,000	"	40	"	"
38,000	"	10	"	"

The increment for this circle is based on Site II, Douglas fir yield tables, and is estimated as being 60% stocked when compared to the stocking from which the Standard yield tables were constructed. It is obtained by a summation of the increments of the various immature age classes taken at one-half the rotation period, thus:

Present Age Years	Area Acres	M. A. I. 40 yrs. hence* feet B. M. per acre	Total M. A. I. 40 years hence—M. feet B. M.
10	38,000	258	9,800
40	6,000	375	2,200
80	31,000	404	12,500

Substituting in Hufnagel's formula:

$$V + (I \times \frac{r}{4}) = \frac{4,000,000 M + 24,500 M \times \frac{80}{4}}{\frac{r}{2}}, Y = \frac{4,000,000 M + 24,500 M \times \frac{80}{4}}{\frac{r}{2}} = \frac{4,000,000 M + 24,500 M \times 20}{40} = \frac{4,490,000 M}{40} = 112,250 M \text{ ft. B. M.}$$

$$Y = \frac{4,490,000 M}{40} = 112,250 M \text{ ft. B. M.}$$

The yields, Y, as obtained by these formulae are used only as an indicative factor

Based on Site II, Douglas fir yield tables, present immature stands stocked 60% standard stocking.

whereby the recommended yield is finally determined, this final yield being made the arithmetical method as mentioned previously."

Costs have depended on the amount of intensive estimating (10 cents per acre) the district plans to keep working plans simple and inexpensive. The Row Plan will cost $7\frac{1}{10}$ cents per acre.

District VII. Washington, D. C. No data received.

APPENDIX F. COMMENT ON WOLFF FORMULA.

The above graph* is based on the figures of table 9. This is intended to depict distribution in volume on 60 acres based on a 60-year rotation, to obtain a normal stock with the yields for each period. Up to the age 20, at which the first yield is given, the growth has been a straight line from the age zero. Then by the yield table method, the normal stock would equal in volume the shaded portion comprising the polygon A-B-C-D-E-F-L-G. The triangle A-O-G is necessarily omitted since its growth that it represents cannot be estimated. To make the yield table method comparable to the original unmodified $\frac{I \times R}{2}$ method of obtaining normal stock, this triangle would in theory have to be included. Now by Moore's method, the normal stock obtained would be included in the triangle G-F-L. The area therein included has to be fairly close to that of the polygon above described, since the portions of the shaded area above the line G-F are almost great enough to balance the unshaded portions included below the line G-F.

On the other hand, by Wolff's formula, the area included is the trapezoid A-F-L-G. Here the growth is a straight line between A-F, as is the case in Moore's formula between G-F. It is patent, in this case, that there is vastly more of the unshaded portion included than there is excluded of the shaded portions; also, that the area would be still more in excess of the yield table method than Moore's formula gives.

Comparisons of the three methods will likely yield similar relative positions. If the mean annual growth *before* rotation age is less than *at* rotation age, especially if the mean annual growth is constantly increasing to a maximum at the rotation age (giving a "concave" curve) and where the age, as in the example given, is very large.

While neither Moore's nor Wolff's formula gives the correct figure (as determined by the yield table) the method suggested by Wolff is mathematically the most correct.

It will be found that the nearer the "estimateable" age approaches the rotation age, the closer will be the results by the Wolff formula to those of the yield table method, and the further away the results by the Moore formula. Vice-versa, the younger the "estimateable" age or the further away from the rotation age, the more closely will the results by the Moore formula and the yield table method approach, and in fact the more accurate will tend to be the original $\frac{I \times R}{2}$ method of obtaining the normal stock.

As pointed out, if the lineaments of the yield curve change,—a not improbable possibility,—these relations will change. The Wolff formula will usually give the correct figures because when approximating the curve by a straight line, the Wolff method is mathematically correct and the Moore formula is mathematically wrong.

* See page 63 for this graph kindly supplied and discussed by Wolff. It was left out after this text was set up that H. H. Chapman had lectured on this problem as early as 1909, but had never published.

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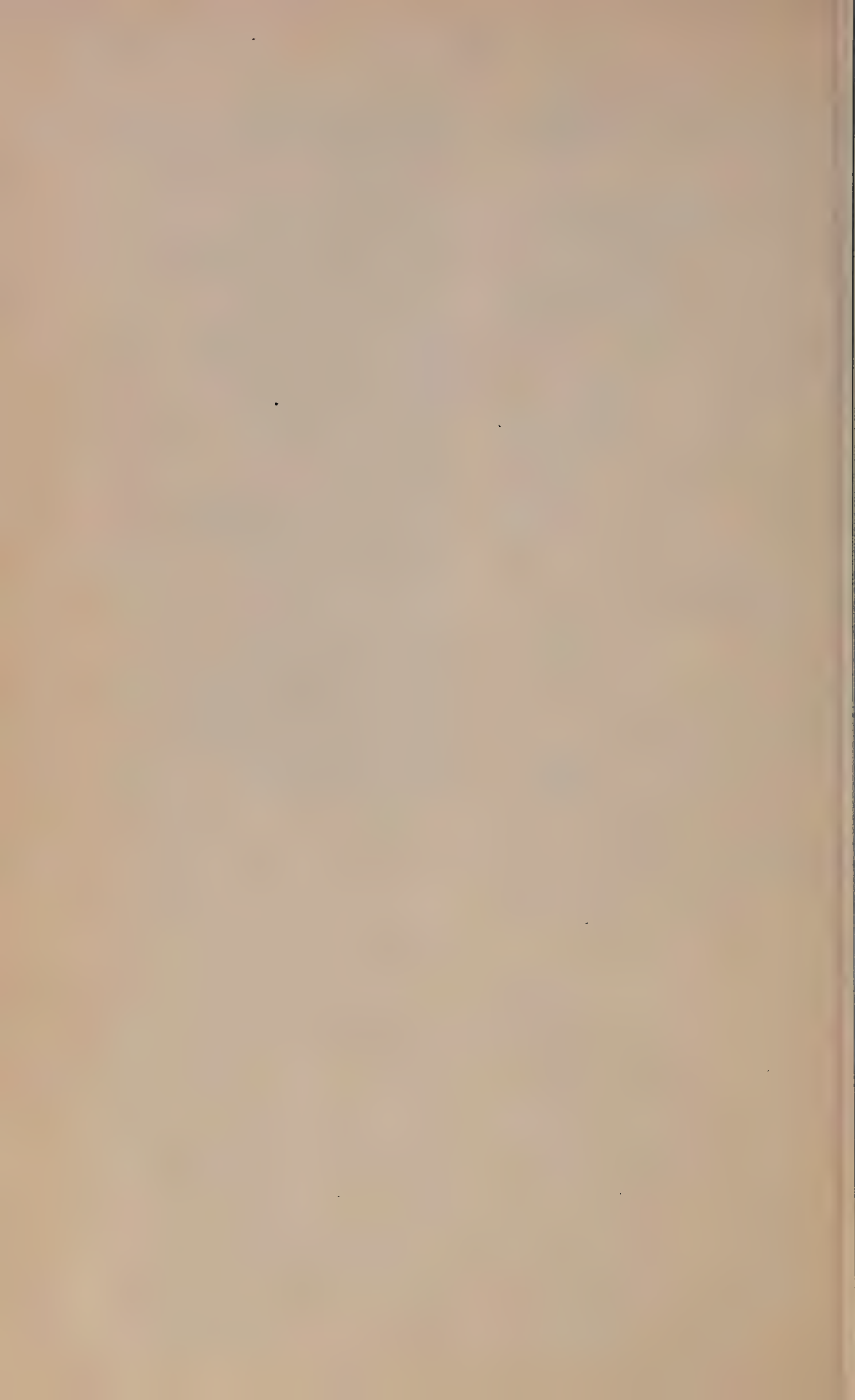
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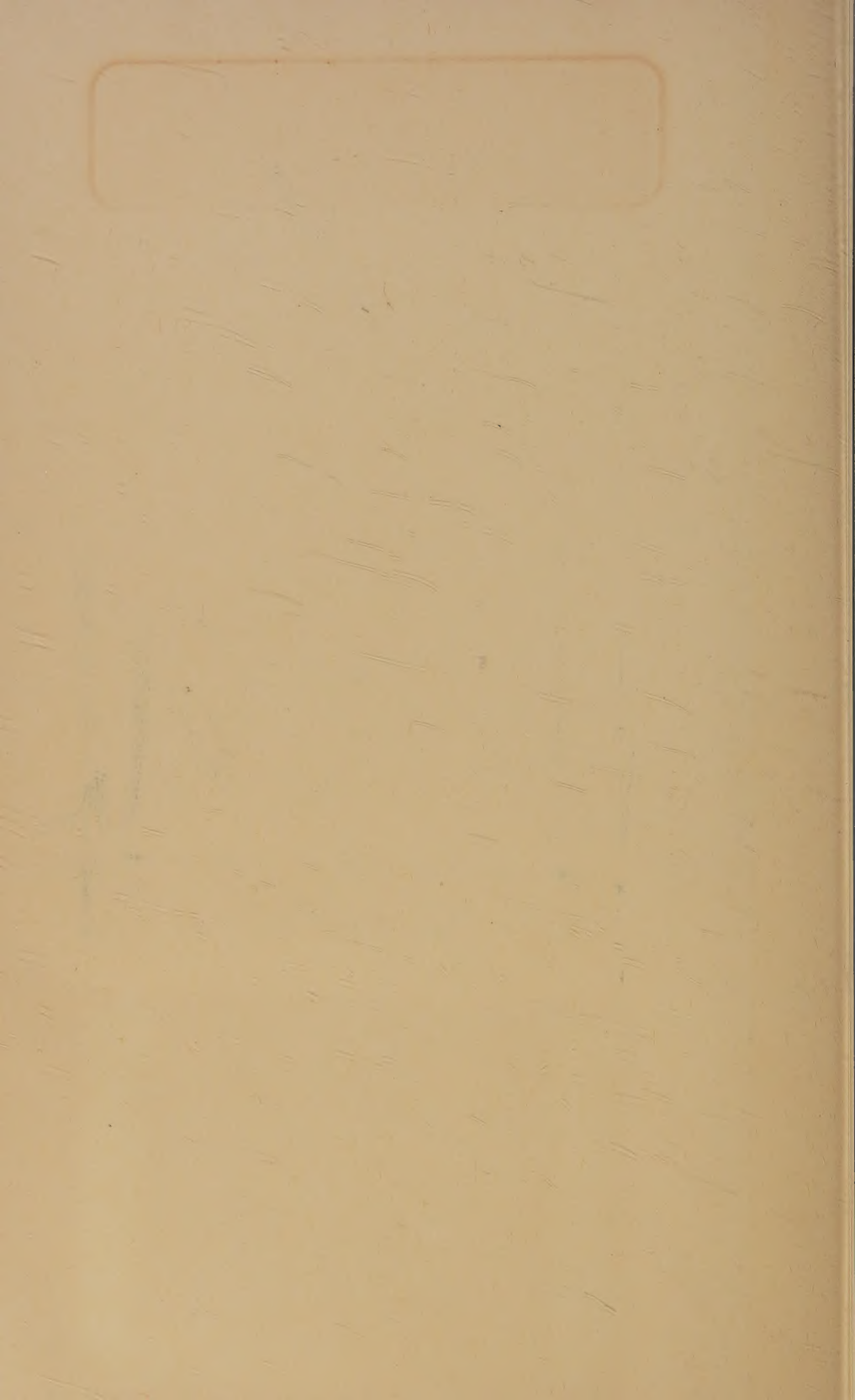
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